POWER PLANT ENGINEERING

Established Over 33 Years

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Parrot Talk

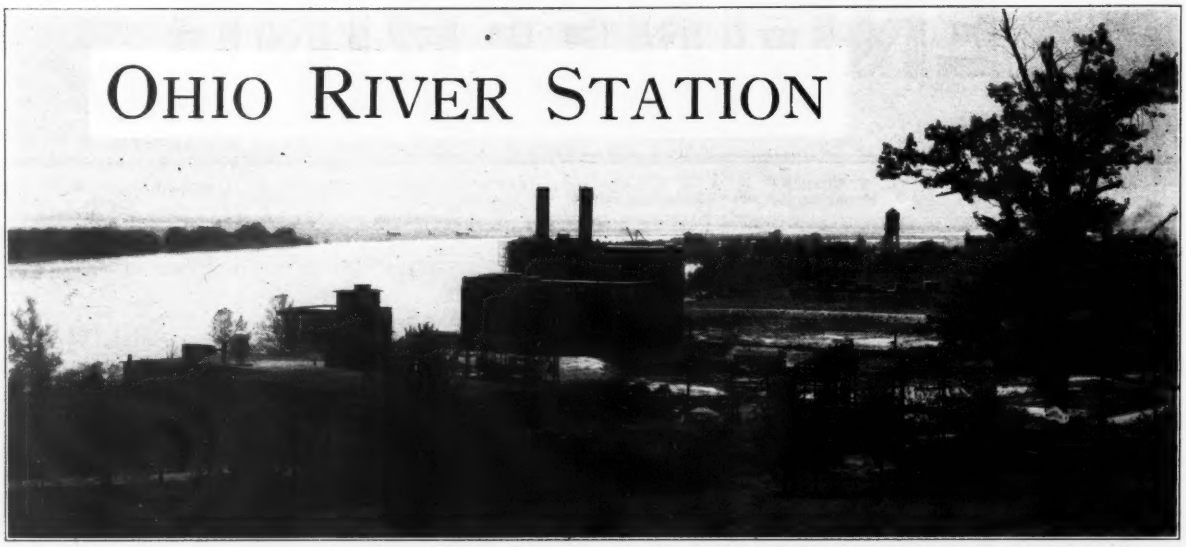
IN THIS WORLD, not all parrot talk is made by the genus Ara or Psittacus; much of it comes from certain species of the genus homo and the familiar "Polly wants a cracker! Pretty Polly!" gives way to "Costs too much! Won't work! Investment not justified!"

Each development is subjected to the same barrage of words. Recently pulverized coal was the target. Now the attack has been switched to high pressures.

From actual costs and estimates, it appears that $105 per kw. of capacity is a reasonable figure for 1200-lb. stations. Cost data both from companies who have built or considered building 1200-lb. plants as presented on page 1158, indicate that a 1200-lb. plant should not be more than $10 a kw. higher than a 400-lb. plant; some say $5 a kw. is a reasonable figure; others feel that there should be little or no difference in cost while still others have pretty well established that a 1200-lb. station should cost less than a 600-lb. station.

With three 1200-lb. stations in operation and four more under construction, performance and costs can be closely estimated. High-pressure plants are firmly established, though, like pulverized coal, admittedly not universally applicable and the human parrots will have to find new fields for their shopworn phrases.

OHIO RIVER STATION



NEW 400-LB. STATION OF THE SOUTHERN INDIANA GAS & ELECTRIC CO. AT EVANSVILLE, IND., HAS INITIAL CAPACITY OF 20,000 KW. IN TWO UNITS. STEAM SUPPLIED BY TWO 1152-HP. BOILERS FIRED BY UNDERFEED STOKERS

LOCATED ON THE BANKS of the Ohio River at Evansville, Ind., the new Ohio River Station of the Southern Indiana Gas & Electric Co. is the latest addition to the rapidly growing list of power stations serving the industrial and domestic demands of southern Indiana.

Designed and constructed by Stevens & Wood, Inc., the new station has an ultimate capacity of 100,000 kw. and an initial capacity of 20,000 kw. in two units; a 7500-kw. unit bled at one stage for feedwater heating and a 12,500-kw. unit bled at three stages for evaporator and for feedwater heating.

In the boiler room two 475 lb. gage pressure (690 deg. F.), 11,520-sq. ft. cross drum boilers, each with 820 sq. ft. of water wall surface, a 2156-sq. ft. interdeck superheater and an 8640-sq. ft. economizer, are fired by 12 retort underfeed stokers. The furnace volume is 5600 cu. ft. and the stokers with a projected grate area of 345.36 sq. ft. are designed to burn about 52 lb. of 11,000-B.t.u. coal per square foot per hour.

DRAFT AND FURNACE ARRANGEMENTS GIVE EXTREMELY FLEXIBLE CONTROL

Maximum output of each unit is around 160,000 lb. of steam per hour with the maximum efficiency point between 50,000 and 70,000 lb. per hr. Both forced and induced draft fans are used, each fan being driven by two motors in order to give flexibility in operation. Low speed on the induced draft fans is used up to about 103,000 lb. of steam per hour and on the forced draft fans up to about 107,000 lb. of steam per hour.

Construction and design of the water walls are shown in Figs. 2 and 3. The walls are made from 4-in. O.D. No. 6 B.W.G. bare tubes set on 6-in. centers and backed by T tile except for a strip covered with cast-iron blocks to a point 3 ft. above the fuel bed. The boiler is equivalent to 13 tubes high and 36 tubes wide with the superheater between what would normally be the eighth and ninth rows. To form a slag screen the first eight rows, that is those below the superheater, are made special with the 2nd and 4th rows omitted entirely, every other tube omitted in the 1st and 3rd rows and the remaining four rows full.

COAL HANDLING EQUIPMENT ENCLOSED TO ELIMINATE DUST

Each boiler has a 140-t. bunker. Coal handling equipment as now installed will take care of one additional boiler unit for which space has been provided in the present building as shown in Fig. 4. When the station is extended farther than this, a duplicate flight conveyor extending out to the left of the bucket elevator as shown in Fig. 4 will be installed, the bucket elevator as installed being capable of handling a total of 6 boilers.

A number of interesting features are included in the station, among these the steam turbine-driven double-clinker grinders, the first of this kind built, and the arrangement of the traveling screens. Instead of the usual arrangement where the water flows straight through the screen, this installation is made so that both sides and bottom of the screen are effective, the water flowing in the sides and bottom as shown in Fig. 5.

A complete system of vacuum cleaning is provided and the boiler room, painted throughout with aluminum paint, gives an appearance of light and cleanliness unequaled in power plant construction. The coal bunkers, elevating and conveying equipment is entirely enclosed and the effectiveness of this construction is shown by Fig. 6, a view of the flight conveyors and economizer floor after several weeks' operation.

As shown by the flow diagram, Fig. 8, the 7500-kw. turbine is bled at one point for feedwater heating with the 324-sq. ft. heater drained back to the hotwell of the

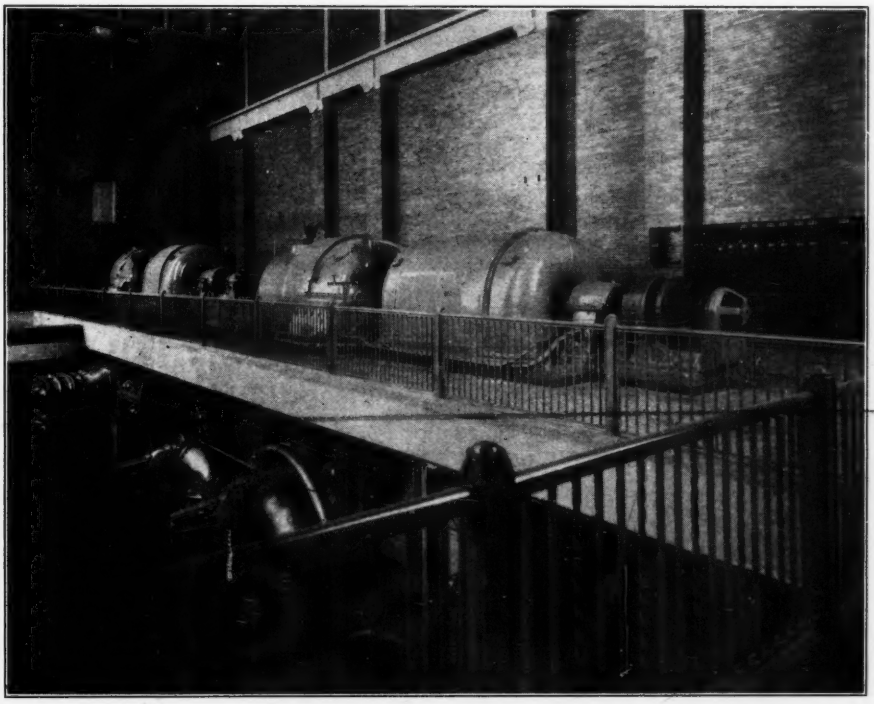


FIG. 1. TURBINE ROOM OF THE OHIO RIVER STATION WITH THE 12,500-KW. UNIT IN THE FOREGROUND AND THE STATION POWER SWITCHBOARD AT THE EXTREME RIGHT

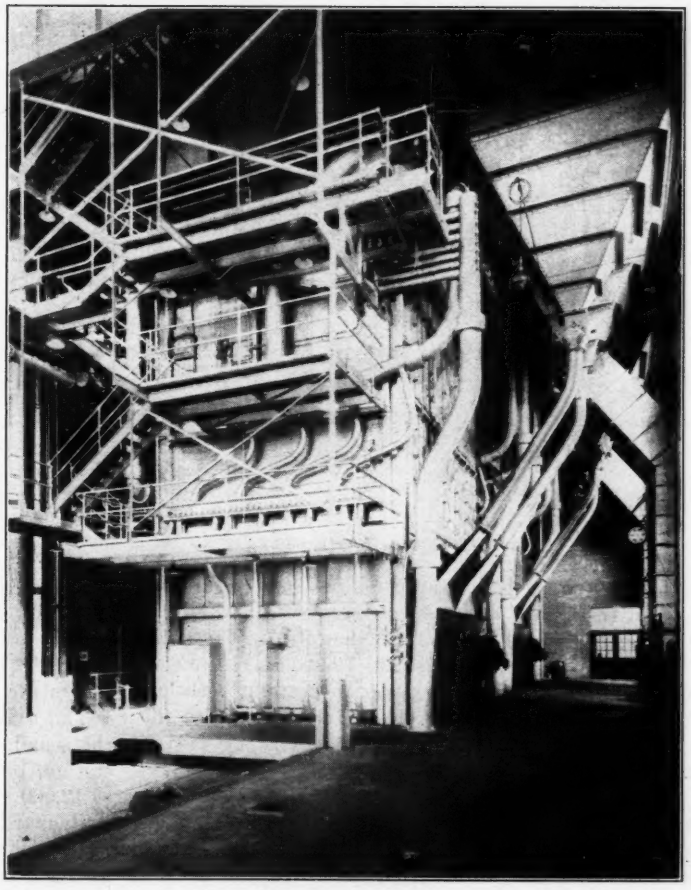


FIG. 2. ALUMINUM PAINT, USED THROUGHOUT THE BOILER ROOM, ADDS GREATLY TO THE CLEANLINESS AND ATTRACTIVENESS OF THE STATION. EACH BOILER UNIT IS CONTROLLED FROM A POINT DIRECTLY IN FRONT OF THE STOKER ON THE OPERATING FLOOR. ALL FANS ARE ON THE ECONOMIZER FLOOR WHILE THE BOILER FEED PUMPS ARE LOCATED ON THE BASEMENT FLOOR ADJACENT TO THE CONDENSER AUXILIARIES. SPACE IS PROVIDED IN THE PRESENT BUILDING FOR A THIRD UNIT

16,500-sq. ft. condenser. The large turbine is designed for extraction at four points, at 190, 81, 31 and 7.27 lb. abs. pressure respectively. The first point, originally intended for cracking scale from the evaporator is not used; the second is used for the evaporator, while the last two are used for the intermediate and low-pressure extraction heaters of 475 and 656 sq. ft. respectively. Drains from the intermediate pressure heater are cascaded to the low-pressure heater and from this heater pumped to the condensate line immediately ahead.

A surge tank is provided between the second extraction heater and the boiler feed pumps. This surge tank, shown at the left of Fig. 6 is provided with a high and low water control valve. With high water in the surge tank, the condensate is sent to the 70,000-gal. clear well before passing through the extraction heaters; with low water, makeup from the clear well is admitted to the condenser which acts as a deaerator. Constant level is maintained in the condenser hotwells.

All boiler makeup is evaporated city water, the evaporator feed being heated in the open heater supplied with steam from the steam-driven auxiliaries. Both the vapor and drains from the evaporator are introduced into the system at the intermediate bleeder heater which acts as an evaporator condenser. In emergencies city water can be used either in the clear well or direct to the suction of the boiler feed pump without contaminating what water may remain in the former.

Circulating water pumps are all installed in the screen house at the river's edge and so located that even in extreme low water they have a positive head on the suction. Normally water for the 16,500-sq. ft. condenser serving the 7500-kw. unit is supplied by one 12,500-g.p.m. pump and the 15,000-sq. ft. condenser serving the 12,500-kw. unit is supplied by two 9500-g.p.m. pumps, although these two systems are cross connected for emergencies.

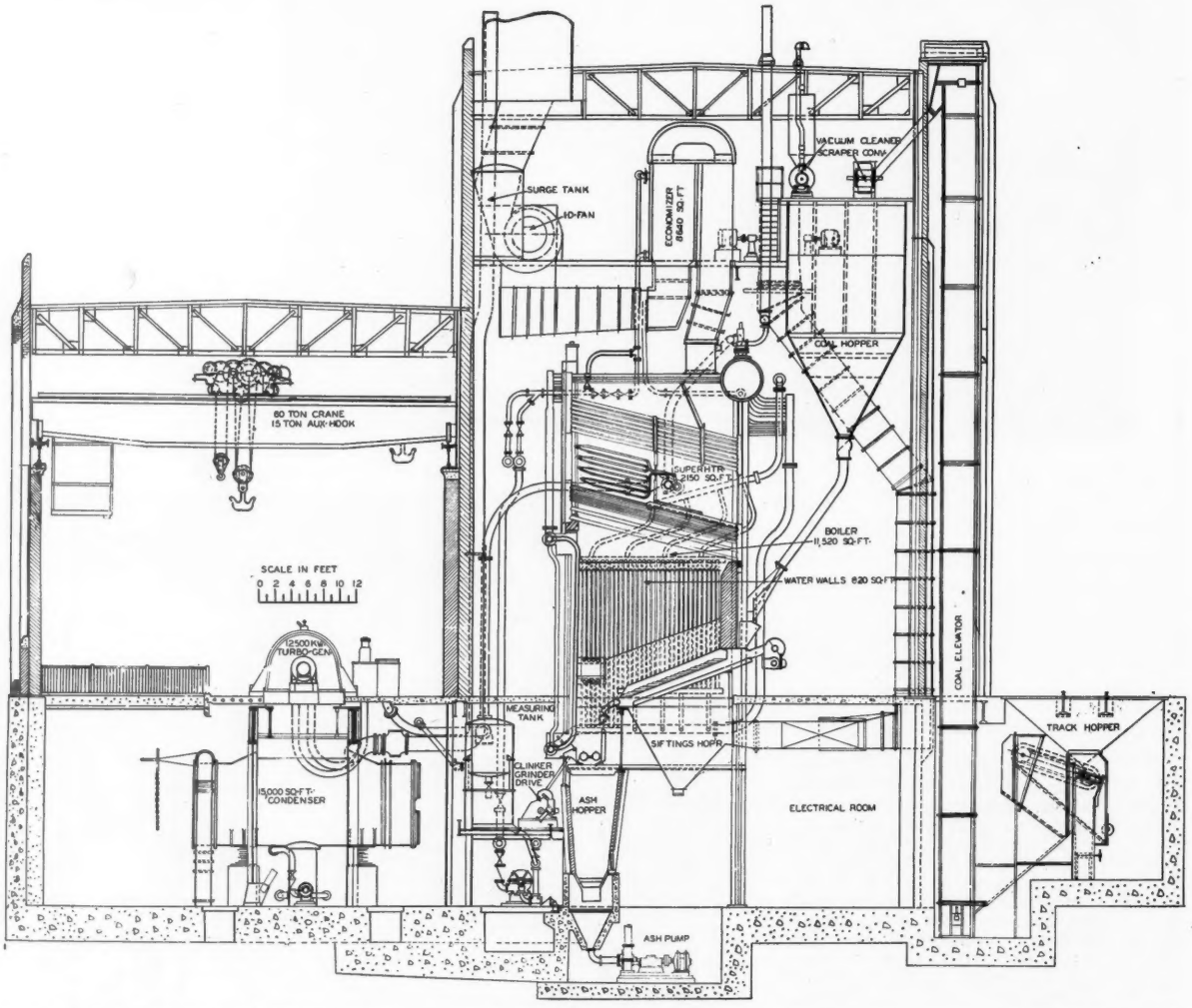
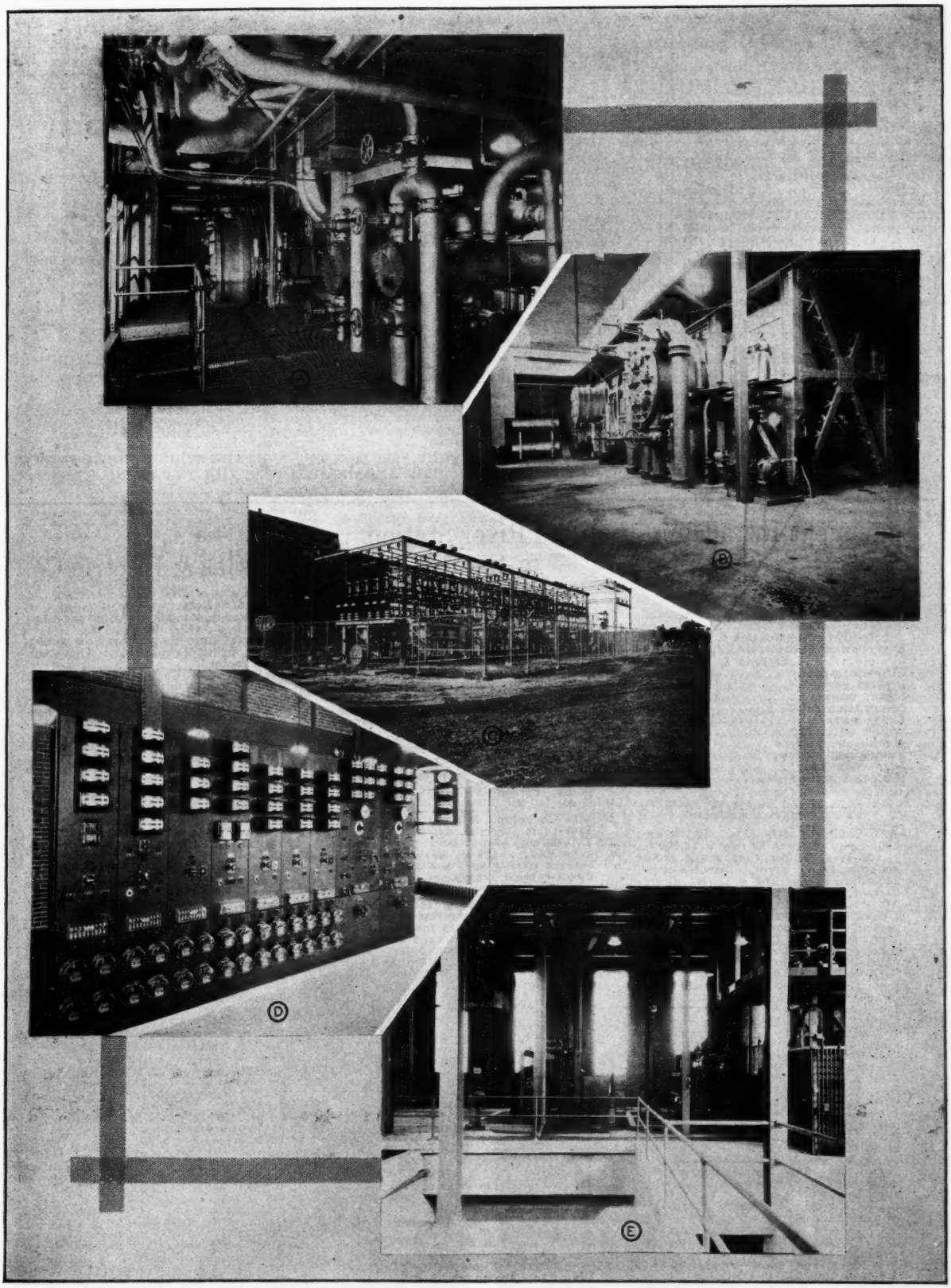


FIG. 3. A CROSS SECTION THROUGH THE STATION SHOWING THE BOILER, TURBINE AND AUXILIARY ARRANGEMENT

All Auxiliary Motors Operate on 440 V.

On the larger machine, power is generated at 12,500 v. and sent directly to a nearby 34.5-kv. substation; on the small machine, purchased previously for another station, power is generated at 4000 v. and stepped up to 12,500 v. by a three-phase transformer located in the switchyard. Station auxiliaries are all 440 v., this power being supplied through three 750-kv-a., 12,500-kw., 480-v. transformers installed in the electrical room located beneath the boiler room floor. This location is



A. EXTRACTION HEATERS. B. CONDENSER FLOOR SHOWING OIL TANK IN BACKGROUND. C. SWITCH YARD. D. MAIN SWITCHBOARD. E. GROUND FLOOR OF SCREEN HOUSE

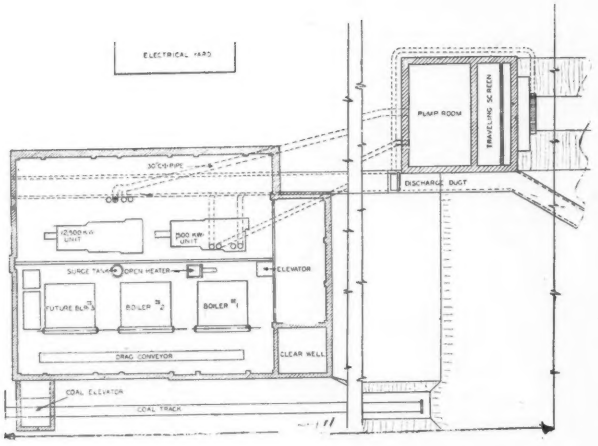


FIG. 4. PLAN SHOWING THE SCREEN HOUSE, SWITCHYARD AND STATION ARRANGEMENT. THE DREDGED INTAKE CHANNEL EXTENDS WELL OUT INTO THE STREAM, TO PROVIDE AMPLE COOLING WATER EVEN AT LOW WATER. A BYPASS FROM THE DISCHARGE TUNNEL TO THE INTAKE IS PROVIDED TO ALLOW RECIRCULATION AND PREVENT ICE FORMATION IN WINTER

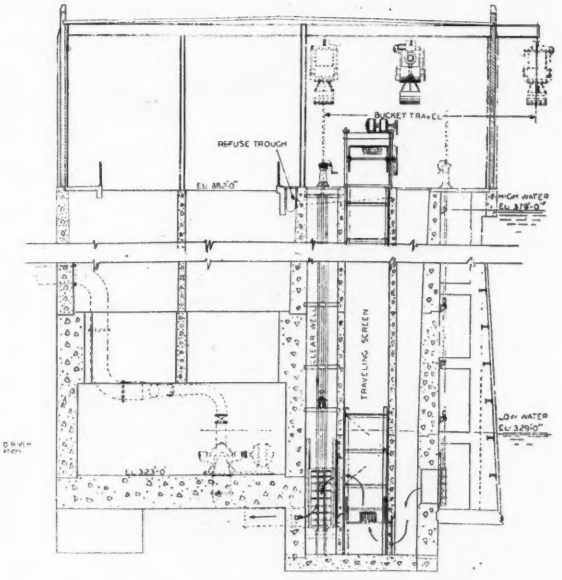


FIG. 5. SECTION THROUGH THE SCREEN HOUSE SHOWING THE ARRANGEMENT OF THE TRAVELING SCREENS

Equipment Installed in the Ohio River Station of the Southern Indiana Gas & Electric Co.

GENERAL

Location .....Evansville, Ind.
Operating company .....
..Southern Indiana Gas & Electric Co.
Engineers and constructors.....
.....Stevens & Wood, Inc.
Ultimate capacity .....100,000 kw.
Present capacity .....20,000 kw.
Steam pressure.....375 lb. gage
Steam temperature.....690 deg. F.
Boiler surface .....11,520 sq. ft.
Water wall surface.....820 sq. ft.
Superheater surface .....2150 sq. ft.
Economizer surface .....8640 sq. ft.
Furnace volume .....5600 cu. ft.
Projected grate area.....345 sq. ft.

TURBINE ROOM

1—Allis-Chalmers Mfg. Co., 12,500-kw., 1800-r.p.m. turbine driving a 12,500-v., 15,625-kv-a., 80-per cent power factor generator; a 250-v., direct-current, 240-amp., exciter and a 125-v., direct-current, 32-amp. pilot exciter.

1—Allis-Chalmers Mfg. Co., 15,000-sq. ft., 2-pass, divided water box, spring supported, surface condenser with 2860—1-in. O.D., No. 18 BWG, Admiralty tubes, 20 ft. long. Tubes rolled both ends.

1—Griscom-Russell Co. 7488-sq. ft., 6-pass, style F generator air cooler.

1—Griscom-Russell Co., 636-sq. ft., 4-pass, low-pressure extraction heater, consisting of 390—⅝-in. O.D., No. 18 BWG, Admiralty tubes. Receiving steam at 7 lb. absolute pressure, 177 deg. F. and designed to heat 150,000 lb. of water per hour from 81 to 170 deg. F. with 9.9 ft. pressure drop through the heater.

1—Griscom-Russell Co., 475-sq. ft., 2-pass, intermediate pressure extraction heater, consisting of 253—⅝-in. O.D., No. 18 BWG, Admiralty tubes, receiving steam at 30 lb. absolute, 250 deg. F. and designed to heat 150,000 lb. of water per hour from 170 deg. to 237 deg. F. with a pressure drop through the heater of 4 ft.

1—Griscom-Russell Co., Riley horizontal evaporator, designed to evaporate 7500 lb. of steam per hour from 55 to 56 deg. F.; feedwater, using 80 lb. abs. steam at a saturated temperature of 312 deg. F. and a heat content of 1241 B.t.u. per lb. Heating surface, 252 sq. ft. of 1 in., No. 18 BWG, Admiralty tubes; relieving surface, 53.5 sq. ft.; shell designed for 50 lb. per sq. in. pressure; coils and manifolds for 200 lb. per sq. in. pressure.

2—Allis-Chalmers Mfg. Co., 1—6-in. suction, 2—3-in. discharges, 2-stage, 350-g.p.m., 155-ft. head, 1750-r.p.m. condensate pumps, driven by 25-hp., 440-v. motors.

1—Croll-Reynolds Co., 3-stage, twin, steam jet air pump, each side with a capacity of 20 c.f.m. at 2 in. of mercury and 70 deg. F. Steam consumption, 440 lb. per hr. of 300 lb. steam.

1—Croll-Reynolds Co. air meter.

1—Griscom-Russell Co. extraction heater drainer.

1—Allis-Chalmers Mfg. Co., 2½ by 2-in., 80-g.p.m., 135-ft. head heater drain pump, driven by a 7½-hp., 440-v. motor.

1—Allis-Chalmers Mfg. Co., 7500-kw., 1800-r.p.m. turbine, driving a 4000-v., 9375-kv-a., 80-per cent power factor generator; a 125-v., 360-amp., direct-current exciter and a 7½-kw., 125-v., direct-current, compound wound pilot exciter.

1—Elliott Co., 16,500-sq. ft., 2-pass, divided water box surface condenser, 3280 1-in. O.D. Muntz metal tubes, 18 BWG, 20 ft. long, packed at one end and rolled at the other.

1—Griscom-Russell Co., U-fin generator air cooler, 4-pass, 8520 sq. ft.

1—Elliott Co., 2-stage twin ejector.

2—Elliott Co., 350-g.p.m. hotwell pumps, driven by 1800-r.p.m., 20-hp., 440-v. Ridgeway motors.

1—Elliott Co., 4-pass, 324-sq. ft. extraction heater.

1—American Steam Pump Co., 2½-in., single-stage, style HBM, 100-g.p.m., 125-ft. head, steam jet starting pump, driven by an Allis-Chalmers 10-hp., 1750-r.p.m., 440-v. motor.

1—American Steam Pump Co., size 1, receiver set for draining the drip tank. With two 25-g.p.m., 50-ft. head centrifugal pumps, driven by General Electric 1750-r.p.m., 2-hp., 440-v. motors.

1—American Steam Pump Co., size 5, HHBM, 700-g.p.m., 250-ft. head ash sluice pump, driven by a Wagner 75-hp., 1750-r.p.m., 440-v. motor.

1—Cleveland Crane & Engineering Co., 60-t. crane with a span of 47 ft. 6 in. and a 15-t. auxiliary hoist.

1—Pennsylvania Pump & Compressor Co., Class 3A, 10 by 10-in., 100-lb., 275-r.p.m. air compressor, close belted to a Wagner 50-hp., 440-v., 1150-r.p.m. motor.

1—Sharples Specialty Co., centrifuge.

1—Blackmer Rotary Pump Co., size 4, oil pump, geared to a Lincoln 3-hp., 1800-r.p.m., 440-v. motor.

1—Viking Pump Co. rotary oil pump, driven by a ¼-hp., 110-v. Allis-Chalmers motor.

1—Viking Pump Co., rotary oil pump, driven by a ¾-hp., 110-v., Allis-Chalmers motor.

2—S. F. Bowser & Co., Richardson-Phoenix type 7A 400-g.p.m. oil filters.

1—York Mfg. Co., size 322 unit heater.

1—Hollister Whitney Co., 7000-lb., 100-ft. per min. freight elevator with Cutler-Hammer push-button control and both electrical and mechanical interlock. Hotwell control valves, type 235 Fisher liquid control valve.....
.....Fisher Governor Co.

BOILER ROOM

2—Combustion Engineering Co., Hedges-Walsh-Weidner 1152-hp., 475-lb. gage pressure cross-drum boilers, 13 tubes high, 36 tubes wide, with 468, No. 6 BWG tubes 20 ft. 4 in. long; water-cooled side walls 180 sq. ft. each; rear walls 460 ft. each; water-cooled surface made up of 4-in., No. 6 BWG tubes set on 6-in. centers backed by T-tile except for 3 ft. above the fuel bed which is covered with cast-iron blocks; furnace volume 5600 cu. ft.

2—Westinghouse Electric & Mfg. Co., 12-retort, 35-tuyere, steam-turbine underfeed stokers with steam-driven double clinker grinders; projected grate area 345.36 sq. ft.

2—Superheater Co., 2156-sq. ft., 4-loop superheaters designed to heat 110,000 lb. per hour of 400 lb. steam to 690 deg. F.

2—Foster Wheeler Corp., 8640-sq. ft. economizers 18 tubes high, 16 ft. long, 10 in. wide.

2—American Blower Corp. No. 7 forced draft fans, type HS with Fafnir bearings, driven at high speed by a Wagner 75-hp., 440-v., 1150-r.p.m. motor and at low speed by a Wagner 30-hp., 900-r.p.m., 440-v. motor. Capacity at high speed 53,000 c.f.m. of 100-deg. F. air at 5-in. static pressure.

2—American Blower Co., No. 10 Special Sirocco induced draft fans, driven at high speed by a Wagner 175-hp., 440-v., 575-r.p.m. motor and at low speed by a Wagner 75-hp., 428-r.p.m., 440-v. motor. Capacity at high speed 96,000 c.f.m. of 420 deg. F. gas at 6.7 in H_2O.

BOILER ROOM—Cont'd

3—Ingersoll-Rand Co., 550-g.p.m., 1220-ft. head, No. 4, Class HST, horizontal centrifugal boiler feed pumps, two driven by 250-hp., 440-v., 1750-r.p.m., Allis-Chalmers motors, the third driven by a Westinghouse 275-hp., 350-lb. pressure, 2850-r.p.m. noncondensing turbine.

1—Morris Machine Works, 8-in., 1000-g.p.m. (500 lb. of ash), 45-ft. head ash pump driven by an Allis-Chalmers 40-hp., 575-r.p.m., type AR, 440-v. motor.

1—Cochrane Corp., No. 5007, 400-hp. open heater designed to heat 12,000 lb. per hr. of cold water to within 2 to 5 deg. of saturated steam temperature.

1—Fairfield Engineering Co., coal handling system with a capacity of 60 t. per hr. Consisting of: 1—18 by 18-ft. track hopper made from ¼-in. steel plate; 1 apron feeder, 30 in. wide by 7 ft. long; 1—3-ft. wide by 6-ft. long vibrating screen with 3 by 3-in. openings; 1 bucket elevator, 96-ft. between centers consisting of 20 by 8 by 8½-in. buckets traveling at 190 ft. per min.; 1 drag conveyor 87 ft. between centers with 16 by 18-in. flights. Bucket elevator driven by 15-hp., 900-r.p.m. motor and flight conveyor driven by 7½-hp., 900-r.p.m., 440-v. Wagner motor through DeLaval gears; flight conveyor equipped with Dodge Timken roller bearings; screen driven by 1-hp., 440-v., 1800-r.p.m. Wagner motor and the feeder driven by a 5-hp., 900-r.p.m., 440-v. Wagner motor through DeLaval gears.

1—Allen-Sherman-Hoff Co., Hydro-jet ash sluice designed to use 665 g.p.m. of water at 100 lb. pressure.

1—Allen Air Appliance Co., Inc., vacuum cleaner, consisting of 1—type 5M exhauster, driven by a 25-hp., 3600-r.p.m.. 440-v. motor.

2—American Steam Pump Co., 1½-in. Type SEM duplex vertical float controlled sump pump, 50 g.p.m. against 40-ft. head, driven by a Master G. E., 2-hp., 3-phase, 490-v., 1800-r.p.m. motor.

1—Hollister-Whitney Co., 1000-lb. automatic elevator with Cutler-Hammer push-button control and both mechanical and electrical interlock.

Damper control, Dean.....Cutler-Hammer Mfg.. Co.
Steel boiler panels.General Electric Co.
Draft gages.....Jos. W. Hays Corp.
Flow meters.....Bailey Meter Co.
Coal spouts, Non-Seg.....Rolland Gardner Co.
Blast gates.....W. S. Rockwell Co.
Safety valves .....Consolidated Ashcroft Hancock Co.
Soot blowers .....Diamond Power Specialty Co.
Water columns and gage glasses.....Yarnall-Waring Co.
Blowoff valves.Edward Valve & Mfg. Co.
Feedwater regulators, Copes.....Northern Equipment Co.
Sprocket rims on valves.....I. N. Bartlett Co.
Stoker counters..R. E. Martin Mfg. Co.

SCREEN HOUSE

1—Ingersoll-Rand Co., size 18 N.F.V., 12,500-g.p.m., 35-ft. head, 690-r.p.m., single-stage centrifugal circulating pump, driven by an Allis-Chalmers 150-hp., 440-v. induction motor.

2—Ingersoll-Rand Co., 9500-g.p.m., 30.8-ft. head, 690-r.p.m., size 16 N.F.V. single-stage centrifugal circulating pumps, driven by Allis-Chalmers 100-hp., 440-v. induction motors.

2—American Steam Pump Co., style HBM, 600-g.p.m., 170-ft. head, 1750-r.p.m., 4-in. general service pumps, driven by Wagner 40-hp., 440-v. motors.

2—American Steam Pump Co., vertical, type SEM, 50-g.p.m., 70-ft. head duplex sump pumps, driven by General Electric 5-hp., 1750-r.p.m., 440-v. float controlled motors.

2—Chain Belt Co., Rex traveling screens, 4 ft. wide, 68 ft. between centers with a capacity of 168-cu.-ft. per sec. when submerged to a depth of 17 ft. 6 in. passing through clean water at 1.8 ft. per sec. Driven at 10 ft. per min. through Jones speed reducers by an Allis-Chalmers 5-hp., 1200-r.p.m., 440-v. motor.

1—Shepard Electric Crane & Hoist Co. crane with a Blaw-Knox grab bucket.

6—Rodney Hunt Machine Co., type 3036 sluice gates.

1—Hollister-Whitney Co., 1000-lb. manlift, 134 ft. per min., with Cutler-Hammer push-button control and with both electrical and mechanical interlocks.

OTHER ELECTRICAL AND MECHANICAL EQUIPMENT

1—Allis- Chalmers Mfg. Co., 10,000-kv-a., 3-phase, 60-cycle, 4000 to 12,800-v. water-cooled outside type transformers.

3—General Electric Co., 750-kv-a., single-phase, water-cooled, 12,800 to 480-v. transformers.

1—Exide Storage Battery Co., 60-cell storage battery, Type EOGO 13.

1—Wagner Electric Corp., 5½-hp., 440-v., 1750-r.p.m. motor, driving a 3-kw., compound-wound, 125-v., direct-current generator.

1—Rochester Electric Products Corp., 140-v., 14-amp., 1750-r.p.m. diverter pole generator, driven by a Westinghouse 3-hp., 440-v. motor.

Ammeters.....General Electric Co.
Watthour meters .....Westinghouse Elec. & Mfg. Co.
Recording watt meter.....General Electric Co.
Voltmeters.....General Electric Co.
Voltage regulator .....Westinghouse Elec. & Mfg. Co.
Meter test blocks.....The States Co.
Temperature recorders .....Leeds & Northrup Co.
Bus bar supports.....Delta Star Electric Co.
Circuit breakers .....Condit Electric Mfg. Co.
Disconnects .....Electric Engineering Equipment Co.
Switchboards.....General Electric Co.
Turbine panels....General Electric Co.
Lightning arrestors .....Westinghouse Electric & Mfg. Co.
Overload relays .....Westinghouse Electric & Mfg. Co.
Signal transmitter...General Elec. Co.
Motor starters and switches—Cutler-Hammer, Inc., General Electric Co., I. T. E. Circuit Breaker Co., Trumbull Elec. Mfg. Co.
Valves—Chapman Valve & Mfg. Co., Consolidated Ashcroft Hancock Co., Crane Co., Edward Valve & Mfg. Co., The Lunkenheimer Co., Walworth Co.
Fittings.Stockham Pipe & Fittings Co.
Insulation.....Johns-Manville Co.
Absolute pressure gages.....C. J. Tagliabue Mfg. Co., Taylor Instrument Companies
Boiler meters.....Bailey Meter Co.
Pressure gages—The Bristol Co., Consolidated Ashcroft Hancock Co., Crosby Steam Gage & Valve Co.
Thermometers.....The Bristol Co., Precision Thermometer & Instrument Co., C. J. Tagliabue Mfg. Co.
Condenser leakage tester.....Leeds & Northrup Co.
Turbine oil .....Vacuum Oil Co.
Lockers.....Terrell Equipment Co.
Wash fountain .....Bradley Wash Fountain Co.

CONTRACTORS

Building brick.....Standard Brick Co.
Labor for brick work, concrete and excavation..C. Kanzler & Sons, Inc.
Structural steel erection.....Price Bros. Co., R. E. Townsend Corp.
Piping installation.....H. E. Ysberg
Piping.....Murray W. Sales
Window sash..The William Bayley Co.
Window glass.....Central Glass Co.
Structural steel and coal bunkers.....Wisconsin Bridge & Iron Co.
Steel for screen house.....International Steel & Iron Co., Geo. L. Mesker & Co.
Breeching and ducts.....Muskegon Iron Works
Boiler brick work.....Boland Construction Co.
Insulation.....S. P. Conkling

FIG. 6. ECONOMIZER FLOOR WITH INDUCED DRAFT FAN

FIG. 7. CIRCULATING AND GENERAL SERVICE PUMPS

somewhat unusual but has proved very practical and uses space which would otherwise be wasted.

Manlifts and a 7000-lb. freight elevator have been provided while the turbine room is served by a 60-t. crane. A machine shop with a pipe cutter, lathe, drill press, power hack saw and grinder are also included. Both turbine and boiler room instruments and controls are centralized in single panel for each unit. A central oil centrifugal system is installed, oil drained by gravity to the dirty oil tank is heated by low-pressure steam coils and centrifuged before storing in the clean oil tank. During operation oil for both units is filtered continuously.

Operating Results of the Plant

Although not as large or elaborate as some recent stations, the plant is well adapted for the load conditions and cheap coal of that region, while, for finished detail, general appearance and facilities for repairs, it has few equals. During construction, no records were broken but the schedule was maintained in spite of heavy rains during the excavation period and the first turbine was rolled the latter part of June, just one year to a day from the time excavation was first started.

At 375 lb. pressure, 690 deg. F. and at its most efficient load of 10,790 kw., the water rate of the turbine is 9.59 lb. per kw. or, considering the auxiliaries, 10.19 lb. per kw-hr. sendout. At an assumed capacity factor of 40 per cent, the station was designed for 18,100 B.t.u. per kw-hr. sendout and it is a tribute to both the designers and operators that every month of operation the station has equaled or bettered the design figures for the conditions under which it operated.

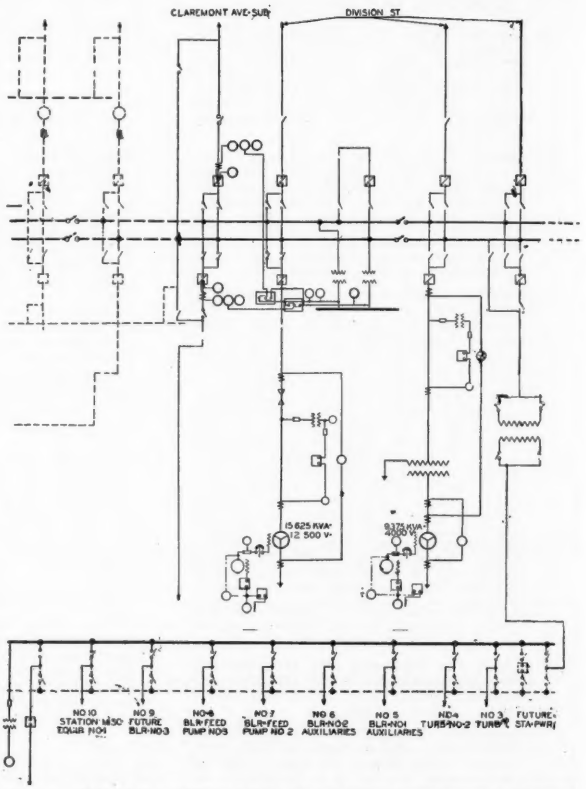


FIG. 9. SINGLE LINE DIAGRAM OF THE PRESENT STATION AND PROVISION FOR FUTURE UNITS

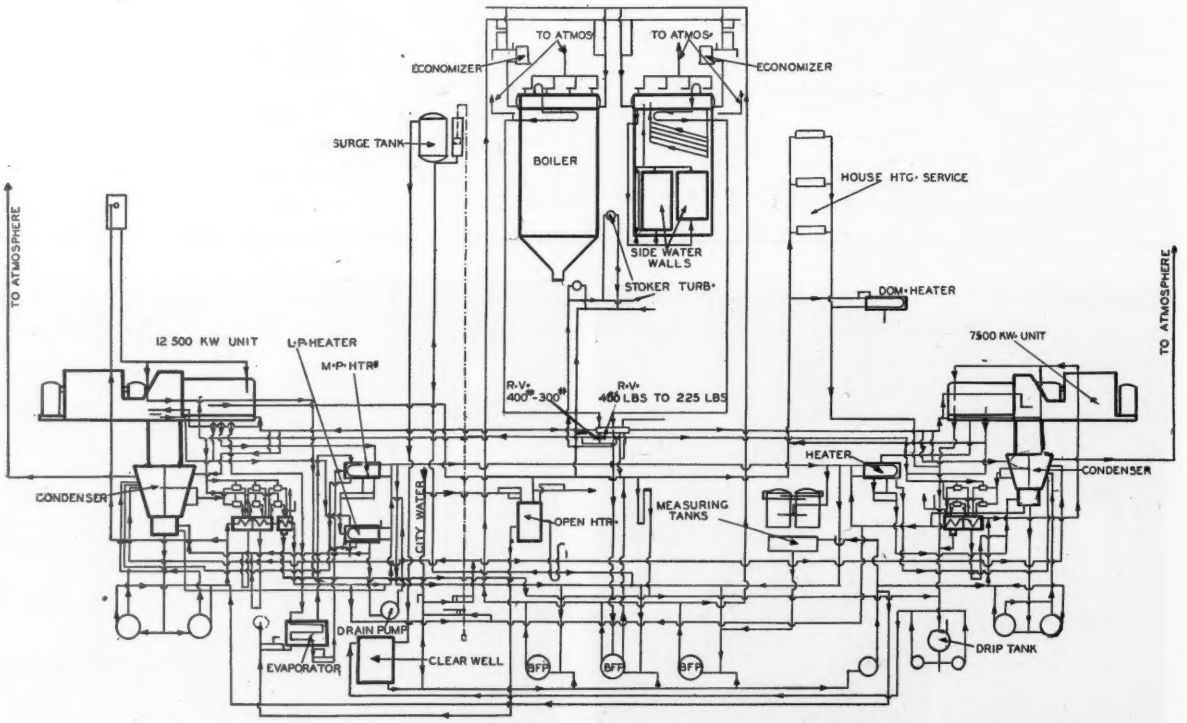


FIG. 8. FLOW DIAGRAM OF THE STATION. THE LARGE UNIT IS BLED AT THREE POINTS

Purchasing Coal for Isolated Steam Plants

AN INVESTIGATION, BASED ON ACTUAL TESTS CONDUCTED BY THE REGULAR HELP IN A STEAM PLANT AND PLANT'S ADJUSTMENT TO THE GRADE OF COAL PURCHASED. BY H. O. SWOBODA*

FOR A GREAT MANY plants, furnishing steam for power in industrial enterprises or for heat in large buildings or for both, the purchase of the necessary coal is taken care of by a purchasing agent or somebody else who cannot devote to this one item in his charge, sufficient time to do it justice. Quite often this agent is likely to guide himself merely by the price quoted per ton and to consider the qualities of the various coals offered not of sufficient importance to determine which coal would be the most advantageous to purchase.

This question, whether the proper kind of coal was being purchased, was raised by the owners of a plant consisting of four 374-hp. boilers. In the past, the engineer had merely reported that a certain coal burned better than some others and the purchasing agent to a certain extent guided himself by this statement, but in purchasing, principally took the price of the coal under consideration and nothing else.

In connection therewith, it may also be stated that the engineer operated his plant by "eyesight," with the exception of the steam pressure gage, not using any of the instruments such as CO_2 meters and draft gages, which, however, were all available.

Upon the owners' request, five kinds of coal were tested, which are being mined in the neighborhood of the plant. They are enumerated in this report as Nos. I to V and the tests were made a part of the regular operations of the plant, as it was considered best not to arrive at any results which afterwards could not be duplicated. Therefore, the figures given do not represent the maximum that might be obtained by operating under the most favorable conditions, such as working the boilers at a rating which results in the highest efficiency.

The tests consisted of the following: The analyses of the various coals; the analyses of the refuse (ash); the steaming qualities of the various coals; observations regarding the smoke developed and the actions of the coals on the furnace equipment.

Feedwater and its treatment, being the same during all tests, was eliminated from the studies and not considered as essential for this investigation.

METHOD OF TAKING SAMPLES

Coals were received at the power plant from the various dealers, were crushed in the usual manner and delivered by the larry car to the boilers. From each larry car load of coal delivered to the stokers, a sample of the coal was taken; that is, one sample was taken from each half ton consumed during the three days. These samples were stored in a covered bucket, so as to preserve the moisture in the coal. At the end of the three days, the samples stored in the bucket were thrown on the floor and thoroughly mixed and quartered; one quarter of this mixed sample was taken and mixed further and quartered and so on until a composite sample of the coal consumed during the three days in proper quantity was delivered to a reliable laboratory for test. The refuse (ashes, etc.) samples were gathered in a similar manner.

TABLE I. COAL AND ASH ANALYSES

COAL ANALYSES	I	II	III	IV	V
Moisture, %	0.64	1.25	0.92	0.51	0.95
Volatile Matter, %	26.65	29.35	18.88	24.87	28.36
Fixed Carbon, %	59.35	61.59	73.76	60.17	59.40
Sulphur, %	2.05	1.24	0.96	2.80	1.60
B.t.u. per lb.	13201	14091	14659	13017	13729
Ash					
% of 1 lb. of coal	13.36	7.81	6.44	14.45	11.29
% based on No. I coal	100	60	50	111	87
ASH ANALYSES (Refuse)					
Sesqui-oxide of Iron, %	19.04	14.72	20.48	21.44	14.56
Combustible Matter, %	30.68	32.42	22.99	41.54	53.24
Ash, %	69.32	67.58	77.01	58.46	46.76
Softening Point, deg. F.	2460	2420	2500	2420	above 2600

Test results of the various analyses are shown in Table I. From the figures for the coal samples, it will be noticed that—

1. Coal No. III has a minimum amount of moisture; Coal No. II the most.
2. Coal No. III has the smallest amount of volatile matter; Coal No. V the largest.
3. Coal No. III has the highest amount of fixed carbon; Coal No. I the lowest.
4. Coal No. III contains the smallest amount of sulphur; Coal No. IV the largest.
5. Coal No. III furnishes the greatest number of heat units (B.t.u.) per lb.; Coal No. IV the least.
6. Coal No. III produced the least amount of ashes; Coal No. I the greatest.
7. Coal No. III produced only one-half of the amount of ashes that Coal No. I produced; Coal No. IV 11 per cent more.

From the figures for the ash samples, it will be noticed that—

1. The refuse of Coal No. V contained the least amount of sesqui-oxide of iron; No. IV the greatest.
2. The refuse of Coal No. III contained the smallest amount of combustible matter; No. V the largest.
3. The actual amount of ash contained in the refuse of Coal No. III was found to be fully 77 per cent; for No. V, only 47 per cent.
4. The ash of the refuse of Coal No. V shows the highest temperature for its softening point; No. IV the lowest.

COAL PURCHASE SPECIFICATIONS

Specifications were developed from the foregoing analyses under which the coals shall be purchased in the future and for establishing a regular system of inspection. In accordance with these specifications, all coal purchased shall conform to the following:

1. All coal shall be what is known in the trade as "run of mine," such as found in and near the steam plant and conform to the following:

(a) It shall show by calorimeter test not less than 13,700 B.t.u.

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(b) It shall show by chemical test not more than 10 per cent ash.

(c) It shall show by chemical test not more than 2 per cent sulphur.

These specifications constitute the minimum standard for quality.

2. Any deficiency of any grade coal furnished under the above specifications will be penalized by deducting from the bills:

(a) For each 100 B.t.u. or a proportionate part—1 cent per ton.

(b) For ash in excess of the amount allowed under the specifications—

For	1	per cent	.....	2	cents	per ton
"	2	" "	.....	4	"	" "
"	3	" "	.....	7	"	" "
"	4	" "	.....	12	"	" "
"	5	" "	.....	20	"	" "
"	6	" "	or more	50	"	" "

(c) For sulphur in excess of the amount allowed under the specifications, 10 cents per ton for each one-half of 1 per cent or fraction thereof.

3. Samples will be tested monthly or more often in case it should become necessary. A reserve portion of the sample will be kept at the office of the laboratory and will on demand be furnished the contractor so that he can verify the results of the laboratory.

Steaming Test Data

Before starting the steaming tests, the instruments at the steam plant were all checked and recalibrated in order to avoid any possible mistake. The tests were then conducted under the supervision of the chief engineer who reported on a form especially prepared for this purpose the readings which he took and attended to the curve drawing instruments. The results of these records are compiled in Table II together with the findings

TABLE II. STEAMING TEST DATA

	I	II	III	IV	V
Boilers operated during test, No.	1,2,4	1,2,3,4	1,4	1,4	1,4
Total No. of hours of test.	39	34	38	32	38
Steam Pressure:					
Maximum, lb.	210	205	192	191	191
Minimum, lb.	162	150	132	144	95
Average, lb.	189.0	183.0	180.3	181.0	179.7
CO_2					
Maximum, %	20.0	20.0	20.0	20.0	20.0
Minimum, %	1.0	0.0	1.0	0.0	3.0
Average, %	7.36	9.05	8.07	10.10	8.80
Feedwater Temperature:					
Maximum, deg. F.	206	200	201	203	202
Minimum, deg. F.	163	138	162	166	166
Average, deg. F.	193.0	179.5	187.0	183.5	186.0
Steam generated per lb. of coal	9.3	9.5	10.46	9.25	8.57
Boiler Efficiency, %	73.0	71.0	74.5	74.3	65.1
Boiler Rating, %	96.5	113.0	113.0	115.0	103.0

based on the calculations which were made from the test figures. From these figures, it will be noticed that—

1. The tests were made on the various boilers as operations required them. Boilers Nos. 1 and 4 were used the most.

2. The tests extended over a period of from 32 to 39 hr. for each kind of coal during which, at times, a change from one boiler to another was made. The test reports clearly mark such changes and other minor details.

3. The steam pressure was maintained as nearly as possible at 185 lb. but, as can be seen from Table II, varied from a minimum of 132 lb. to a maximum of 210 lb., the average ranging from 179.7 to 189.0 lb.

4. An attempt was made to maintain the CO_2 at about 10 per cent but as can be seen, it ranged from a minimum of 0 per cent to a maximum of 20 per cent, the average ranging from 7.36 to 10.0 per cent.

5. The feedwater is intended to have a temperature of 210 deg. F., but during the tests never exceeded 206 deg. F. and dropped at times to 138 deg. F., the average ranging from 179.5 to 193.0 deg. F.

6. Coal No. III developed the largest amount of steam per lb. of coal; Coal No. V the least.

7. The boilers are intended to operate with an efficiency of 75 per cent but during the tests never exceeded 74.5 per cent and dropped as low as 65.1 per cent.

8. The boilers operated during the tests varied from 96.5 per cent to 115 per cent of their rated capacity.

From these figures, it will be noticed that considerable variations took place while the tests were going on and it is for this reason that in fairness to the coals tested, certain adjustments in the calculations had to be made for a just comparison. These variations undoubtedly can be reduced in the future, as when the chief engineer started these tests, he was obliged to operate with a force practically unskilled and had to adjust the boilers as best he could while going along.

Adjustment of Steaming Test Data

As already stated, it was necessary to adjust the steaming test data of Table II in order to make a just comparison. The results of this adjustment are presented in Table III, in which corrections were made for obtaining the figures for the feedwater at 210 deg. F., the boiler pressure at 185 lb. and the boiler efficiency at 75 per cent. With these adjustments, Coal No. III leads with 10.77 lb. of steam generated per pound of coal and Coal No. IV produced the least with 9.59 lb. Expressing these figures in per cent, assuming Coal No. I as generating 100 per cent (9.7 lb.) No. III coal would produce 111 per cent and No. IV 98.8 per cent.

TABLE III. ADJUSTMENT OF STEAMING TEST DATA

	I	II	III	IV	V
Actual test figures from Table II:					
Steam generated per lb. of coal	9.3	9.5	10.46	9.25	8.57
Feedwater Temp., deg. F.	193.0	179.5	187.0	183.5	186.0
Boiler Pressure, lb.	189.0	183.0	180.3	181.0	179.7
Boiler Efficiency, %	73.0	71.0	74.5	74.3	65.1
Adjustments in lb. of steam:					
Feedwater to 210 deg. F.	+ 0.15	+ 0.28	+ 0.24	+ 0.24	+ 0.20
Boiler Pressure to 185 lb.	— 0.0	+ 0.0	+ 0.0	+ 0.0	+ 0.0
Boiler Efficiency to 75%	+ 0.25	+ 0.55	+ 0.07	+ 0.10	+ 1.31
Steam generated per lb of coal (adjusted):					
in lb.	9.70	10.33	10.77	9.59	10.08
in per cent	100.0	106.6	111.0	98.8	104.0

From a mere technical point of view, Coal No. III leads; the next best is Coal No. II by 4.4 per cent and the poorest is Coal No. IV, lagging by 11.2 per cent.

Quality vs. Price of Coal

Percentages of steam generated by the various coals as outlined above, together with some other points which have to be considered, can be used as a basis for determining the value of the various coals for an economical operation as compared with the prices named by the various dealers. The results of such a study are compiled herewith as can be seen from the following:

1. The prices named by the dealers vary from $3.10 for Coals No. I and II to $4.25 per ton for Coal No. III.

2. The difference in the value of the coals based on their steaming qualities as already mentioned in Table II permits for Coal No. III a higher price by 34 cents and for Coal No. IV a lower price by 4 cents as compared with the price for Coal No. I.

TABLE IV. QUALITY AND PRICE

Description	I	II	III	IV	V
Prices Offered					
Per ton of coal	$3.10	$3.10	$4.25	$3.50	$3.15
Valuation of Coals Based on Test Results					
Value of coals based on their steaming qualities, as per last line of Table III	100%	106.6%	111%	98.3%	104%
Quantity of refuse to be handled as per last line under Coal Analyses in Table I	100%	60%	50%	111%	67%
Base Price	$3.10	$3.10	$3.10	$3.10	$3.10
Adjustment in cents to be added to or deducted from $3.10 for their steaming qualities	.00	+.18	+.34	—.04	+.12
Total	$3.10	$3.28	$3.44	$3.06	$3.22
Adjustment in cents, based on cost of handling No. 1 refuse at 35 cents per ton to be added to or deducted from $3.10	.00	+.14	+.18	—.04	+.12
Valuation of coals based on $3.10 for No. 1 coal adjusted in accordance with their steaming quality and cost of refuse handling	$3.10	$3.42	$3.62	$3.02	$3.34
Valuation reduced to percentage, taking No. 1 as 100 per cent	100%	110%	117%	97%	108%

3. The difference in the amount of the ashes produced as shown in the last line under coal analyses in Table I permits for Coal No. III a higher price of 18 cents and for Coal No. IV a lower price of 4 cents as compared with the price for Coal No. I.

4. Combining the two adjustments for steaming quality and ash handling, it can be seen that the merits of the various coals can be expressed in comparison with Coal No. I as indicated in Table V.

TABLE V. BASE PRICE—$3.10

No. of Coal	Merit Per Cent	De-merit Dollars	Actual Value	Price Offered
I	100%	0.00	$3.10	$3.10
II	110%	+0.32	3.42	3.10
III	117%	+0.52	3.62	4.25
IV	97%	—0.08	3.02	3.50
V	108%	+0.24	3.34	3.15

This table clearly shows that Coals No. I, II, and V can be purchased at price below or at their actual value, whereas Coals No. III and IV are offered at prices considerably above their actual values. Therefore, the purchase of Coals No. III and IV should not be considered from an economical point of view unless the prices offered are reduced to their actual value.

There are, of course, a great many other points influencing the value of the coal, such as the moisture and sulphur contents, the action of the coal on the furnace equipment and the amount of smoke developed. Neither of these points, however, is likely to have such a large influence on the actual value as to change the sequence of the values given in the Table V. Only one thing should be given careful consideration and that is the amount of combustible matter in the refuse, which, according to Table I, varies fully 100 per cent, viz., from 22.99 per cent for Coal No. III to 53.24 per cent for Coal No. V. This variation clearly indicates that Coal No. III with only 22.99 per cent combustible matter in the refuse well consumed under the most favorable conditions, whereas the setting of the furnace equipment for Coal No. V with 53.24 per cent combustible matter in the refuse was decidedly unfavorable. In fact, the combustible matter of all five coals is considered excessive and it is safe to assume that with the proper adjustment of the furnace equipment, it can be reduced to less than 25 per cent.

Conclusions

Based on the foregoing, we have arrived at the following conclusions:

1. Coal No. III is the best sample tested, but cannot be considered due to its excessive price.

2. Coal No. II from an economical point of view is the best to purchase, provided it can be secured in sufficient quantities. We are informed, however, that the sample consisted of the best pieces of the average run and cannot be duplicated in quantities.

3. Coal No. V from an economical point of view is the second best to purchase, provided it is possible to readjust the furnace equipment in such a manner that the combustible matter of the refuse is reduced from 53.24 per cent to 25 per cent or less.

4. Coal No. I is the third best and has given satisfactory operations during the past few years.

These tests have also proved that the operation of the plant so far as the firing of the coal is concerned, can be materially improved upon and in connection therewith, we are submitting the following recommendation:

The adjustment of the furnaces should be arranged in such a manner that the percentage of combustible matter in the refuse does not exceed 25 per cent. It is quite evident that a considerable part of the coals passed through the furnaces without having a chance of being burned for either one or all of the following reasons. 1. That the stoker speed is too fast. 2. That the drafts are insufficient to furnish the necessary air for the combustion. 3. That the coal bed is not maintained of sufficient thickness to withstand a more intensive draft at a slower speed of the stoker and that for this reason it should be made thicker, although the draft should be increased proportionately more. 4. That at times insufficient CO_2 was being produced. 5. That upon award of the coal contract, a new test should be made extending preferably over several weeks and that the adjustment of the furnace equipment should be changed once a week in order to determine the most efficient operation.

As the outcome of this investigation, the owners purchased Coal No. II. Just as soon as it was used, the entire neighborhood complained about excessive smoke and it became necessary to adjust the boilers in accordance with the suggestions outlined, before it was possible to obtain satisfactory operation.

In most cases, approximate coal analysis, giving the moisture, volatile matter, fixed carbon and ash as percentages, is sufficient. The ultimate analysis is a chemical analysis giving the carbon, hydrogen, nitrogen, sulphur and ash as percentages. Sulphur is usually determined for approximate analysis but is not included as part of the 100 per cent.

Initial Costs of Power Plants Compared on a PRESSURE BASIS

ESTIMATES AND ACTUAL COSTS SHOW THAT ADDITIONAL EXPENSE OF HIGH PRESSURE RANGES FROM $5 TO $10 PER KW. OF CAPACITY HIGHER THAN FOR MODERATE PRESSURES

DUE TO THE rapidly increasing number of plants which are using the 1200 to 1400-lb. cycle, widespread interest regarding the cost of power stations for this pressure has been created. It is generally thought that the increased cost of the 1400-lb. plant over that of a 350 or 450-lb. plant of the same capacity is a considerable item which is justified only by greatly increased efficiency.

TABLE 1. RELATIVE COSTS OF 400 AND 1400-LB. INSTALLATIONS BASED ON ACTUAL PLANTS, AS REPORTED BY STEVENS & WOOD

	Cost - Dollars per Kw.	
	Toronto 140,000 kw. 400 lb. Pressure	Deepwater 159,000 kw. 1400 lb. Pressure
Land	$0.82	$1.57
Preparation of Site	1.64	0.21
Yard work	4.42	4.48
River front work		2.68
Foundations	15.93	4.16
Building	10.78	10.11
Piping (not including circulating water)	4.75	5.09
Boiler room equipment	23.41	31.01
Turbine room equipment	26.47	21.34
Electrical switching equipment in station)	12.11	8.98
Service Equipment	2.43	5.37
Coal handling	4.67	3.19
Step-up substation	6.68	6.62
Preliminary operation	0.74	0.50
Total	$114.85	$105.31

As a matter of fact, a comparison of the 400-lb. Toronto Station and the 1400-lb. Deepwater Station shows that the cost, excluding land, site preparation, yard work and foundation costs, which will vary with the location of the plant, is almost identical. On the basis of 140,000 kw., Toronto Station cost $92.04 per kw. of capacity and Deepwater Station, on the basis of 159,000 kw., cost $92.21 per kw. of capacity.

FIG. 1. DEEPWATER STATION, THE FIRST COMPLETE 1200-LB. STATION TO BE BUILT. COSTS ARE TABULATED IN TABLE I

From the following costs and cost estimates which have been selected from previous issues of Power Plant Engineering and from N.E.L.A. reports, it appears that the difference in costs should not exceed $10.00 per kw. of capacity while the majority place increased cost around $5.00 per kw. of capacity. It is interesting to note that the estimates of those companies that have actually built 1200-lb. stations are considerably lower than the estimates of the companies that have not built such stations, indicating that actual costs run below estimated costs, probably due to the decreasing cost of high-pressure equipment as it comes into wider use.

The commercial economy of increasing the operating pressure has been questioned by many engineers wherever operating pressures are discussed. Probably the reason for this skepticism lies in the fact that it is not appreciated that the cost of a particular part of the station is but a small proportion of the actual unit cost of the complete station.

ANALYSIS SHOWS WHY HIGHER PRESSURE DOES NOT GREATLY INCREASE TOTAL COST

This is well brought out in Fig. 3, the approximate split-up of the cost of various parts of a steam electric generating station for normal pressure. A study of this chart shows why it is possible to build a 1200-lb. station at approximately the same unit cost as a 350-lb. station. It is obvious that the unit cost of the switchgear and wiring, switch house and auxiliary equipment, which constitute 22 per cent of the cost of a station, have practically nothing to do with the operating pressure.

Cost of the turbine generators and equipment

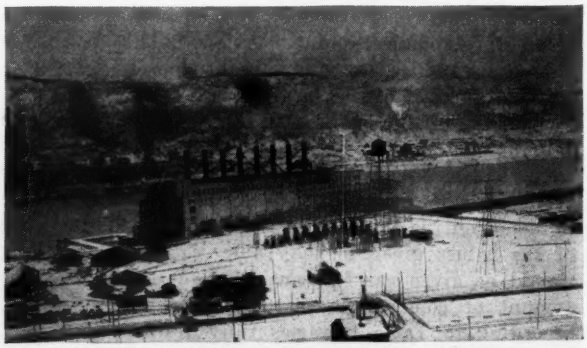

FIG. 2. TORONTO STATION, THE 400-LB. STATION REFERRED TO IN TABLE I

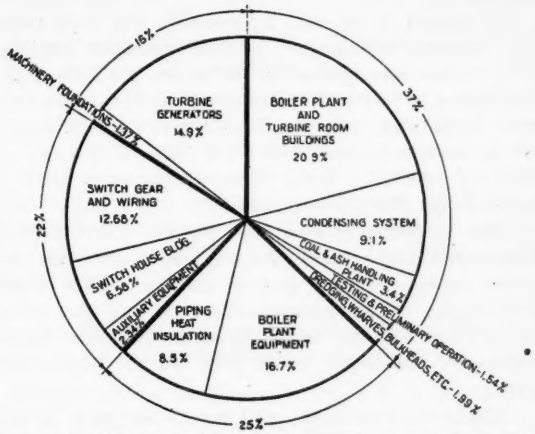

FIG. 3. RELATIVE COSTS OF VARIOUS PARTS IN STEAM AND ELECTRIC GENERATING STATIONS, AS PREPARED BY THE EDISON ELECTRIC ILLUMINATING CO. OF BOSTON

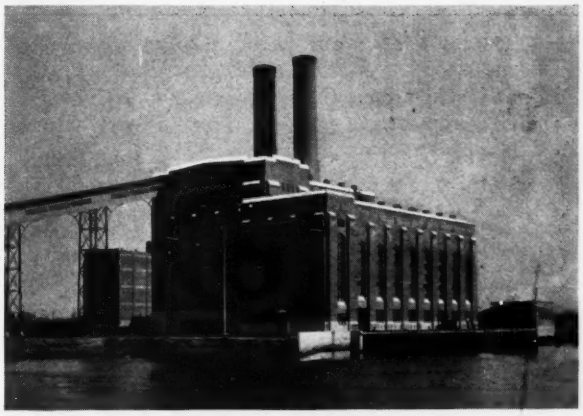

FIG. 4. EDGAR STATION, WHERE THE FIRST 1200-LB. EQUIPMENT WAS PUT IN SERVICE

foundations will amount to slightly more for 1200 lb. than for 350-lb. equipment. These items represent only 16 per cent of the cost of the station so the increase in unit cost is small. Probably the slight difference in cost will disappear in the future as this equipment comes into wider use.

Figures for boiler plant equipment and station piping, which constitute 25 per cent of the cost of the station, will amount to more for a 1200-lb. than for a 350-lb. installation. The increase in unit cost is not as great as might be imagined because of the fact that a 1200-lb. boiler will generate more power than a 350-lb. boiler of the same size. Furthermore, the cost of such equipment as fuel-burning equipment, ducts, cinder catchers and piping, is much less per unit of capacity in a 1200-lb. plant than in a 350-lb. plant and goes a long way toward balancing the higher cost of the high-pressure parts.

Boiler plant and turbine room buildings, condenser system, including intake and discharge tunnels and coal and ash-handling equipment which constitute approximately 37 per cent of the cost of a station, cost materially less per unit of capacity in a 1200-lb. than in a 350-lb. plant. Additional cost of the various major parts which cost more in a high-pressure station when divided by the capacity of the high-pressure elements of cross-compound, generating units will be little if any more than the unit cost of a normal-pressure plant.

Edgar Costs Show Above Assumptions Correct

Experience in building the extension at Edgar Station shows that a properly designed 1200-lb. station need not cost any more per unit of capacity than a 350-lb. station and that it will show a material improvement in economy, so that the increased operating pressure is therefore justified.

Studies made before the high-pressure equipment was put in Edgar showed that it is economical to use steam at as high a temperature as possible, irrespective of the pressure employed. Studies as to the most economical pressure showed that for stations employing the regenerative cycle, but no reheating of the steam during its expansion from throttle to condenser pressure, there would be no commercial economy in going to pressures higher than about 350 to 400 lb. at the turbine throttle. In other words, the fixed charges on the additional cost of the high-pressure equipment would be greater than the fuel savings due to the higher pressures.

When studied from the standpoint of the regenerative-reheat cycle, however, the studies indicated that there would be a decided commercial advantage in raising the operating pressure to somewhere between 1200 and 1500 lb. Conservative estimates of the cost of construction indicated that 1200 lb. was justified and one boiler and one turbine for this pressure were installed and results have confirmed estimates as to costs and economy.

Toronto and Deepwater Costs Compared

From the standpoint of interest and general value, the figures shown in Table I, prepared by Stevens & Wood, are probably the most valuable yet published. These costs, referred to earlier in the article, show the segregated cost of Toronto Station of 400 lb. pressure and Deepwater Station at 1400 lb. pressure so subdivided that comparison of the different parts of the station can be made.

Costs shown for Toronto Station are the final actual costs for a balanced plant having four 35,000-kw. units. These costs include all known expenses in connection with the station up to and including engineering and the engineering fee but do not include interest during construction nor any other corporate expenses of the owning company. Deepwater costs are shown from estimates but as half the total cost has been incurred, a careful survey of the situation shows that the project can be completed within the figures shown.

Deepwater consists initially of two main power units with their boilers, each compound unit having a rating of 53,000 kw. The building space and boilers for a third unit are provided, but in place of a third main power unit, there is installed a high-pressure turbine element only, which with several evaporators, supplies a large amount of industrial service steam. It has, therefore, been necessary to adjust the estimate covering the actual project to make it applicable to three complete power units or a total of 159,000 kw.

Referring to the individual groups in the table, that of land needs no comment, being independent of pressure and governed by the locality and acreage pur-

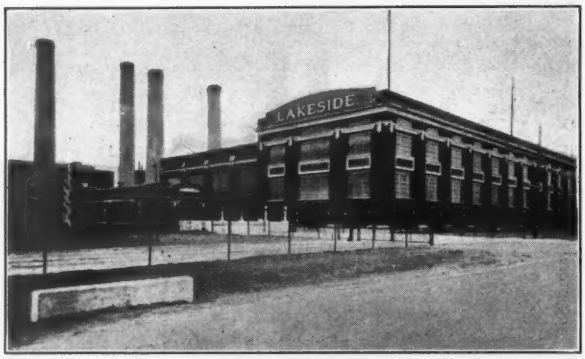

FIG. 5. LAKESIDE STATION, A PIONEER IN BOTH PULVERIZED COAL AND 1200-LB. PRESSURE. COST DATA IN TABLE II

chased. Toronto is high in preparation of site on account of having to move a highway and an interurban traction railway which formerly ran across the site. It is also directly on the Ohio River front and the condensing water intake structures are a part of the building substructure so that their costs came under foundation. At Deepwater, the building is set back some 200 ft. from the edge of the Delaware River and certain water-front structures are separated from the building proper.

TABLE II. DISTRIBUTION OF THE GREATEST COST OF THE HIGH-PRESSURE EQUIPMENT AT LAKESIDE STATION; THE TOTAL DIFFERENCE WAS $5.28 PER KW. OF CAPACITY

Boiler plant and electrical plant equipment	51.5
Superheater and reheater costs	11.8
Piping	16.3
Boiler feed pump	8.6
Electrical	7.6
Miscellaneous	4.2

Referring to the item of foundations, Toronto not only had a greater plan area per kilowatt of capacity but a river rise of over 40 ft. had to be provided for, so that the Toronto foundation structure is a relatively costly one as compared with the simple pile and concrete mat foundation at Deepwater.

The following summary gives some information on the relative foundation and building costs:

Station	Plan Area Sq. ft. per kw.	Volume above Basement Floor Cu. ft. per kw.
Toronto	0.49	63
Deepwater	0.40	40

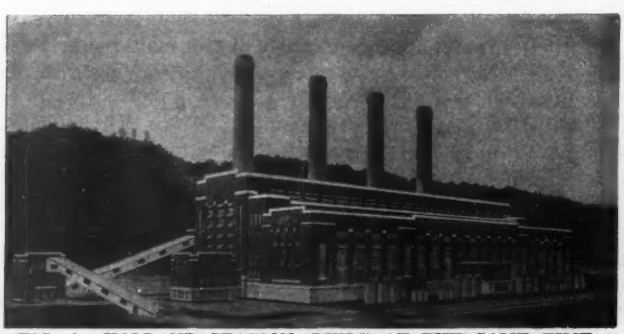

FIG. 6. HOLLAND STATION, BUILT AT THE SAME TIME AS DEEPWATER AT A REPORTED COST OF $105 PER KW. OF CAPACITY

In regard to piping, presumably the true relative cost between 400-lb. and 1400-lb. pressure stations is greater than here shown for the latter. In both stations, the piping is relatively simple but in Toronto it covers four units and eight boilers, while in Deepwater it covers three units and six boilers only. Presumably the difference shown in boiler room equipment is fairly correct for the different pressures.

This is probably also true for the item of turbine room equipment where, with the larger compound units at the higher pressure, part of the unit has a speed of 3600 r.p.m. These comparative costs are also affected by the relatively smaller condensing equipment required because of the better water rates on the high-pressure units.

Electrical switching equipment costs vary with the type and complexity of the auxiliary equipment selected and are not in any way affected by the difference in pressures. Similarly, the remaining groups of costs shown are not affected by pressure, except possibly in coal handling, where the quantity of coal per kilowatt of capacity is slightly less at the higher pressure.

Unfortunately for comparative purposes, the true total relative costs for the two pressures are overshadowed in these figures by the greater differences caused by size of units, foundation conditions and type of auxiliary equipment but these figures and other studies lead us to the belief that a 1400-lb. pressure plant should cost not to exceed 5 per cent more than a 400-lb. pressure plant.

Lakeside Estimates Show Increased Unit Cost of About $5

These conclusions, drawn from the Toronto costs are strengthened by construction costs of Lakeside Station. The greater cost for 1300-300 lb. over all 300-lb. pressure installation at this station was found to be $204,410 on the basis of an addition of 39,100-kw. capacity to an existing station. On a capacity basis, this represents $5.28 per kw. Greater costs for boiler plant equipment and electrical plant equipment were found to be $235,523 and credits of $28,113 were taken for tunnel and circulating water system and for coal handling system. The 1200-lb. turbine is noncondensing and an equivalent tunnel capacity is available for future installations because of greater thermal efficiency of the 1200-lb. equipment.

Distribution of the greater cost for boiler plant

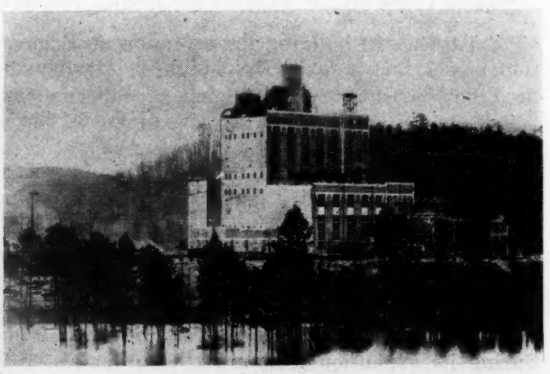

FIG. 7. GORGAS STATION, A 450-LB. HYDRO SYSTEM STANDBY PLANT BUILT AS A RESULT OF STUDIES SUMMARIZED IN TABLE IV

equipment and electrical equipment are shown in Table II. High-pressure installation costs are those of an initial installation but 300-lb. pressure costs are based upon practical experience. In the latter case, advantage was taken of all improvements available to reduce costs; yet in the high-pressure costs appear figures later found unnecessarily high, so that the difference of $5.28 per kw. should be the maximum. Present design of a second high-pressure installation indicates that this margin will decrease.

Holland Station Estimates Show $105 Per Kw. Cost of 1200-Lb. Station

Design studies made in connection with the Holland Station, designed by W. S. Barstow & Co., and described in the March 1 issue of Power Plant Engineering, lead to the same general conclusions; that is, that the relative construction cost differences for 400-lb. and 1200 lb. for stations of approximately 60,000 kw. or larger should not exceed $6.00. These cost figures also showed that a 550-lb. plant with one stage of reheating was more expensive for both first cost and heat consumption than was a 1200-lb. plant, leading to one conclusion; that was, that the station should be designed for either 400-lb. or 1200-lb. pressure. As described in the article mentioned, where coal costs are $3.50 per ton, fixed charges plus fuel cost are about the same in both sizes of plant. Above this, the 1200-lb. plant will give a lower total cost of power while below $3.50 per t. of coal, the 400-lb. plant will be the cheaper to operate.

They found, contrary to what might be expected, a 1200-lb. turbo-generator is now constructed at very little more expense per kilowatt than a 400-lb. turbine and cheaper than 600-lb. reheat units and that the average cost per kilowatt for the first two units will be less than $105.00, including land, engineering, supervision, interest on construction, overhead, outdoor substation and everything necessary to complete the plant in its entirety.

At Northeast Station the Additional Cost of 1200-Lb. Plant Was $8.81 Per Kw.

At Northeast station the difference between 300 and 1400-lb. equipment, based on a 45,000-kw. addition to the existing station, amounted to $8.81 per kw. of capacity, as shown in Table III.

In considering the relative construction costs of a 1400-lb. and a 300-lb. plant, it is evident that this comparison is specific and the difference in costs shown in the table is that which existed in this particular case and not necessarily what might exist elsewhere.

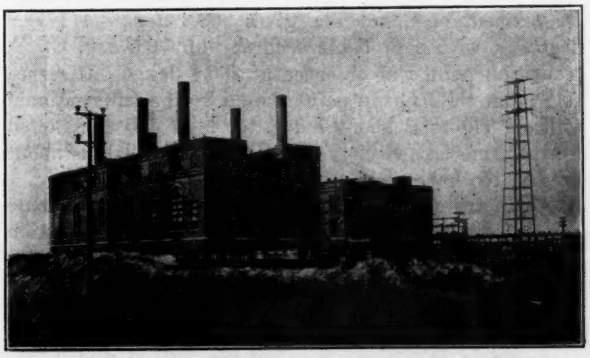

FIG. 8. NORTHEAST STATION, ANOTHER PIONEER IN HIGH PRESSURES. COST DATA ARE TABULATED IN TABLE III

In this study, a 45,000-kw. addition to an existing 300-lb. 130,000-kw. plant was considered, this addition to be either one 10,000-kw., 1200-lb. unit, exhausting to a 35,000-kw., 300-lb. unit, or one 45,000-kw., 300-lb. unit. The figures do not include all the items that would appear in a new plant, but they do express the difference in cost per kilowatt of the two pressures for the above installation.

No charges were made in either case for the building to house the 1200-lb. turbine and the two 1400-lb. boilers, or the three 300-lb. boilers, which were to be placed in an existing extension. The three 300-lb. boilers would have occupied more space, as the 1200-lb. turbine fitted into an unused space immediately adjacent to the 1400-lb. boilers, which simplified piping considerably. No credit was given the 1200-lb. unit for the reduction in coal handling and pulverizing costs and these items are cited to show that, if anything, the 300-lb. unit was favored. The difference in condenser auxiliary power, boiler-feed pump, fan, coal handling and pulverizing power, is expressed in the net B.t.u. difference.

The summary indicates that the 1400-lb. installation in this case would cost $8.81 per kw. capacity more than the 300-lb. unit. The table also shows the difference in B.t.u. for each of the installations and indicates the saving made by the 1200-lb. unit would pay 15 per cent fixed charges on the additional investment if it operated at only 33.8 per cent load factor. The actual load factor is, of course, dependent on the available load and the ability to keep equipment in service.

Load factor of the 1200-lb. unit should not drop off as rapidly as that of a 300-lb. unit over a period of years, as the obsolescence factor is undoubtedly lower. The most economical point of operation of a 1200-lb. unit is at full load and, if the load is available, a 70

TABLE III. AT NORTHEAST STATION, THE HIGH-PRESSURE EQUIPMENT WAS FOUND TO COST $8.81 PER KW. ADDITIONAL MORE THAN 300-LB. EQUIPMENT

Item	1400 lb. Increase (+) Decrease (-)
Boilers, settings, economizers, air heaters fuel burning equipment and soot blowers	+$7.39
Coal bunkers and coal conveyors	- 0.13
Building steel, foundations, floors, breeching, ducts, steel and pipe and duct insulation	- 0.19
Fans, motors and boiler feed pumps	+ 0.01
Piping connections	+ 0.42
Auxiliary power extension	+ 0.73
Miscellaneous electrical labor and material, instruments and painting	+ 0.06
Total	+$8.31
Contingencies, engineering, insurance and interest	+ 1.10
Boiler total (no building)	+$9.41
Turbine, generator and generator air cooler	+ 1.34
New building and foundations	- 0.63
Condenser, auxiliaries, circulating water connections, tunnel and auxiliary power extension	- 1.18
Piping connections	+ 0.12
Miscellaneous, instruments, and crane	+ 0.10
Extraction heaters	- 0.04
Switchboard and switches	- 0.22
Total	-$0.51
Contingencies, engineering, insurance and interest	- 0.09
Turbine room total	-$0.60
Plant Total	+$8.81
Estimated B.t.u. per kw-hr. of 300 lb. plant	16,800
Estimated B.t.u. per kw-hr. of (45,000 kw.) 1400 lb.--300 lb. plant	13,810
B.t.u. saving on 1400 lb.--300 lb. plant	2,990
Load factor necessary to allow additional investment of $8.81 for 1400 lb.--300 lb.plant (Based on 15 per cent fixed charges and a fuel cost of 67,000 B.t.u. for one cent.)	33.8%

per cent or 80 per cent load factor is entirely possible. Whether this or a 50 per cent load factor is used, the saving of a 1200-lb. unit over a 300-lb. unit is quite evident.

Miscellaneous Estimates Agree Well

Estimates of costs made by companies who have not as yet built 1200-lb. stations agree fairly well. Table IV taken from an article in the May 1 issue of Power

TABLE IV. COST ESTIMATE FOR 450, 650 AND 1400-LB. PLANTS MADE BY THE ALABAMA POWER CO.

Plant A - 2-60,000 kw. turbo-generators - 450 lb.
Plant B - 2-52,500 kw. turbo-generators - 650 lb.
Plant C - 2-12,500 kw. and 2-43,000 kw. turbo-generators - 1400 lb.

	Plant A 120,000 kw. 450 lb.	Plant B 105,000 kw. 650 lb.	Plant C 111,000 kw. 1400 lb.
Land, buildings and village	$2,320,000	$2,360,000	$2,100,000
Boiler-plant equipment	2,430,000	2,330,000	2,720,000
Turbo-generator equipment	1,730,000	1,610,000	1,780,000
Condensers and auxiliaries	625,000	575,000	550,000
Station piping	790,000	900,000	1,140,000
Condensing water system	715,000	700,000	650,000
Feedwater system	312,000	350,000	460,000
Coal handling	468,000	450,000	435,000
Service equipment	163,000	165,000	165,000
Electrical & Substation equipment	1,880,000	1,640,000	1,740,000
Total Cost	$11,433,000	$11,080,000	$11,740,000
Cost per kw. of capacity	$95.50	$105.30	$106.90
B.t.u. per kw.hr. sent out at 40 per cent yearly capacity factor	16,000	14,800	14,200

Costs do not include interest and some administrative overheads

TABLE V. INCREASED COST OF 1200-LB. PLANTS AS ESTIMATED BY STONE & WEBSTER

	Per Cent of Total Station Cost	Increase for 1200 lb. Plant	
General improvements, coal and ash handling	13.0%	None	
Buildings and foundations	17.5	-5%	
Turbine generators	17.5	5	
Boilers, furnaces, and heat absorbing accessories	20.0	10	
Fuel preparation, condensing and draft system	15.0	-15	
	83.0%	balanced	
Piping	6.0	25%	1.5%
Feed water system	3.0	50	1.5
Switching	8.0	20	1.5
Contingencies			1.0
	100.0%		5.5%

TABLE VI. HIGH-PRESSURE PLANT ESTIMATES BY THE NEW YORK EDISON CO.

Steam pressure, lb.	1200	1200/400	1400
Capacity basis, kw.	100,000	100,000	100,000
Greater cost for boiler and superheater	$6.00	$3.60	$7.50
Greater cost for piping	4.09	4.09	4.24
Greater cost for turbine	1.00	0.80	1.25
Greater cost for feed water heaters	0.054	0.054	0.059
Credit for circulating system	0.52	0.51	0.52
Net greater cost	10.85	8.17	12.82

Plant Engineering, shows cost estimates for 450, 650 and 1400-lb. plants made some time ago in connection with studies of the new Gorgas steam plant, described in the May 1 issue. Table V is a summary of the relative costs of 1200 and 400-lb. stations, taken from a discussion of a recent A.S.M.E. paper, while Table VI is the summary of an estimate made by the New York Edison Co. giving the relative cost of a station having different steam pressures, other factors remaining constant. Practically the entire difference in cost of the various stations is accounted for by the greater boiler and superheater costs.

Based on costs that are available, and opinions expressed by those who have built and operated 400, 600 and 1200-lb. plants, general conclusions can be reached that 650-lb. boiler reheat stations can be built for about 5 per cent more per kilowatt of capacity than 400-lb. stations without reheat, while a 1200 to 1400-lb. station with boiler reheat should cost no more per kilowatt of capacity than a 650-lb. station of the same type and should give considerably better fuel economy.

Based on 16-yr. effective life and 40 per cent capacity use, with 13,000 B.t.u. coal at $2.25 per ton, Table VII was offered in discussion before the A. S. M. E. as a summary of the relative estimated operating expense in various pressure plants, including fixed charges, fuel, labor and maintenance of a company which has built many stations including 600-lb. reheat and 1200-lb. pressure plants.

TABLE VII. PROBABLE TOTAL COST OF OPERATION OF DIFFERENT TYPE STATIONS

	400-Lb. Plant Table 9	600-Lb. Plant C Revision	1200-Lb. Plant C Revision
Fixed charges, per cent	100	105	105
Coal, per cent	100	92.5	86.6
Labor, per cent	100	100.0	100.0
Maintenance materials, per cent	100	100.0	100.0
Weighted average, per cent	100	101.8	101.0

Considering the rapid increase in use of 1200 to 1400-lb. pressure plants, it is safe to assume that the cost will decrease still further and the differential between the 1200-lb. and the 400-lb. plant will continue to grow smaller.

Melting Point of Potassium Chromate

In view of the fact that the American Society for Testing Materials has recommended that the melting temperature of potassium chromate be used for indicating the temperature to which a coal sample should be heated in the standard method of analysis to determine its volatile matter content, and in view of the apparent uncertainty existing as to this melting point, it has been thought worth while to make a careful redetermination of the datum. It is of interest to determine the melting point not only of the pure salt but also of the commercial product, in order to test its suitability for use as a temperature indicator.

Careful redetermination of the melting point of pure potassium chromate, made at the Pittsburgh Experiment Station of the United States Bureau of Mines, Department of Commerce, gives 968.3 deg. C. (1774.9 deg. F.), with a probable accuracy of ±0.5 deg. C. A transition point was observed at 666.8 deg. C. It seems, then, that the melting point chosen by the International Critical Tables is about 7 deg. too high and that noted by the American Society for Testing Materials is about 28 deg. too low.

Ordinary commercial samples of potassium chromate appear to require a considerable amount of purification before their melting point can be used as an accurate temperature indicator. More detailed information is given in Serial 2917, "The Melting Point of Potassium Chromate," by David F. Smith and F. A. Hartgen, copies of which may be obtained from the United States Bureau of Mines, Department of Commerce, Washington, D. C.

Details of the Organization and Operation of a Large Power Plant

PART III.* PLANT MAINTENANCE, MACHINE REPAIRS, BETTERMENT PROGRAM AND EDUCATIONAL FACILITIES ARE EXTREMELY IMPORTANT. BY J. C. FALKNER†

A CAREFULLY WORKED OUT program of inspection should be carried out on all equipment, for instance inspection of main unit blading at least once a year and inspection of circulating pump impellers every time the unit is down. This is done by entering the discharge piping from the pump and examining the impellers for sticks, and trash. Inspect all the auxiliary turbine blades twice a year. Examine all boiler drums for pitting every three months. Inspect condensate pump impeller for wear due to cavitation. Inspect salt and fresh water service pumps for wear on impeller and sleeves, a careful record being kept to check the trouble with any particular design of apparatus. Photographs of wear or erosion of turbine blades should be made when possible, as they will tell far better than your memory whether the erosion is worse this year than it was in the preceding year.

Revolving screens should be taken up once a year and painted before reinstalling. Plugged condenser tubes should be removed and new ones installed while the turbine is being overhauled.

Boilers, stokers, pulverized coal feeders and pulverized coal mills should be thoroughly overhauled once a year. The boiler drums should be scraped, and the tubes cleaned with a mechanical tube cleaner. In addition, the first six rows should be turbined every six months. Six to ten men are required for this work.

All pumps, auxiliary turbines and gears should be given an inspection every six months.

Combustion control apparatus should have a man or men assigned to it constantly. He should give it very close attention and make adjustments when necessary, as the differential between the first and last pass of the boiler changes due to slag or ashes collecting.

ALL PARTS OF THE STATION SHOULD RECEIVE ATTENTION

The station machine shop should be equipped with the proper equipment to handle, in an emergency, all work except that necessary on main turbine blading or large castings. Four to six machinists with helpers under the direction of a foreman are necessary for this work.

Two or three gangs of pipe fitters should keep all pipe lines in repair and make any small alteration that is deemed necessary. Any large change should be done by a regular construction force.

Turbine oil in the main units should be tested every week and approximately every two or three months it should be run through a separator and allowed to settle before being put back in the system. This necessitates having an extra batch of oil that is ready for use while the one being drawn off is being separated, so as not to keep the unit out of service any longer than necessary.

Men who are responsible for the maintenance of the electrical apparatus and equipment would be under the supervision of a foreman and be divided into three sections, one for the turbine room, one for the boiler room and one for the switch galleries. They should inspect all apparatus, keep brushes on collector rings on main unit generators at proper tension, make regular periodic megger tests on all generators, motors and wiring.

After taking the megger tests, the results should be plotted on a chart. Thus having a chart for each motor and generator a drop in insulation resistance is readily shown. Any sudden drops should be checked again and if the low reading is obtained again, steps should be taken to locate the weak spot.

Rotors of all turbo-generators should be removed at least every three years if a closed system of generator cooling is used and every one to two years if air is taken directly from the atmosphere. The oil switches for the generators, bus ties and feeder should be inspected every month and the oil changed in same.

Transformer oil should be run through a filter press twice a year. Air gaps on motors should be taken every two months to determine the amount of wear in the bearings. Rheostats, controllers and relay contacts should be examined weekly.

SIGNALS SHOULD BE USED

In order to operate with a minimum of verbal instructions and particularly with a minimum of hazard during emergencies, all normal operation and so far as possible all emergency operating should be carried out in accordance with signals and pre-arranged methods.

At present, the large stations cover so much territory and the operating groups are so far apart that it is well to keep the different groups alert by artificial trouble. That is with the load dropping off the station, as at noon or other times. Have the foreman get at some advantageous point for watching the actions of his men and then either order by telephone or trip out a certain piece of apparatus such as a motor-generator set or a house turbine driving a part of the essential auxiliaries.

If a careful system has been worked out, each group affected will immediately take steps to carry the load some other way or get the apparatus affected back into service. No matter how much your men are instructed without the actual doing of the job, there will be a certain amount of confusion.

Time for starting up fans, stoker motors and other equipment in a station having practically all electric drives after some apparatus was purposely shut down was cut from over a minute to fifteen seconds by these methods. When it is considered that some means of

*The third and last of a series of articles. Part I appeared in the August 15 issue and Part II in the October 1 issue.

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communication either by telephone, speaking tube or signal lights has to be established between two or more places and then the starting operation carried out, this is good time.

On a regular day, the superintendent should hold a meeting with the chief engineer, electrical foreman, boiler room chief and their assistants and the chemists and head of the station betterment crew should be present.

A general discussion should be held on the performance of all apparatus in the station and suggestions for improvement of both operating and design conditions. Any subject brought up which requires further attention should be assigned to certain individuals to look after.

Another meeting should be held every afternoon except Saturday and Sunday, at which the heat balance report of the day previous should be discussed. This meeting should be attended by the chief engineer, the boiler room chief and members of the station betterment or test crew.

Test Crews Should Have Complete Instruments

Water rates of the turbines, station water rate, make up water used, temperature of feedwater, pounds of coal used by each boiler (if possible) and the boiler efficiency based on the amount of steam delivered per pound of coal along with any difficulties encountered with fuel or apparatus should be reviewed and methods devised for correction. This meeting should not take much over a half hour, if all the data have been correctly compiled.

Station betterment or test crew should comprise 10 to 15 men, usually young men studying engineering. They are used in figuring daily heat balances, to make any test on boilers, turbines, condensers, etc., to maintain all steam instruments, thermometers, and CO_2 recorders. A systematic schedule of overhauling, cleaning and calibrating of all instruments should be established which insures continuous use of all this equipment, as nothing is discarded quicker than an instrument or gage that is continually out of order. The station betterment crew should also make weekly and monthly reports, this data being plotted on charts for quick reference and comparison.

Heat rate per kw-hr. should be watched carefully and any change in the daily rate accounted for. The B.t.u. value of the coal used on the day before should be known as early as possible in order to determine whether a change in rate is chargeable to the coal itself or to the method of firing.

Chemical laboratories play an important part in the operation of a power plant. Tests of the boiler feedwater and the water in each boiler are made daily, so as to calculate the amount of treatment needed and the extent of blowdown necessary. Tests of coal and ash samples and periodic tests on all oils and greases are advisable. Many other tests such as those on turbine blades, condenser tubes and refractories are made in the laboratory. Five or six men are required for this work.

As fast as a vacancy exists, the operating man should be stepped up; starting as a janitor or laborer he can become an oiler, turbine oiler, assistant engineer, engineer and watch engineer; assistant machinists and machinists; assistant stoker operator, stoker operator, water tender, boiler room engineer; dynamo man, assistant switchboard operator, switchboard operator, or watch foreman.

As far as possible, all vacancies should be filled by one of the men in the same department as that in which the vacancy occurred, as nothing is more demoralizing to a group of men striving to get ahead, than to have an outsider brought in and put over them. When two or more men are considered for the same job, their standing being the same, preference should be given to the man availing himself of some form of study.

Questions on Bulletin Board Increase Interest

Periodic questions concerning apparatus and methods of operation posted on the bulletin boards will usually cause interest to be taken by the newer men. If they cannot answer the questions they will soon find out what they are.

One man, or more if necessary, should be assigned to follow up the installation of all apparatus during any increase in capacity of the station. They should report anything that does not seem right from an operating standpoint, as many times things that look perfect on a blueprint are practically impossible to operate when actually installed.

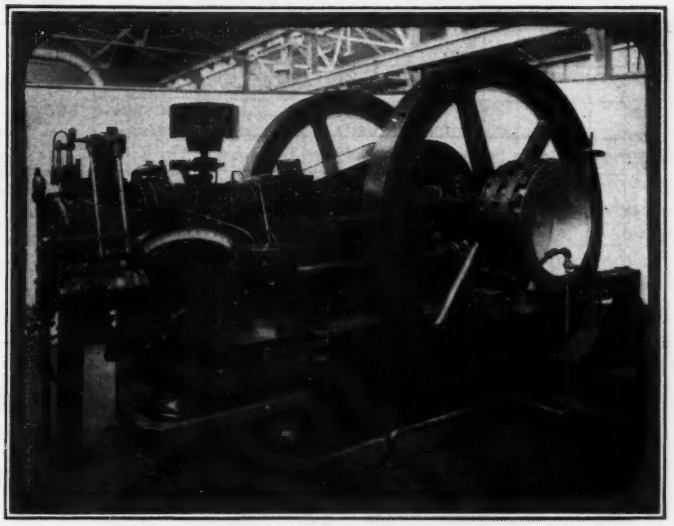
Budget recommendations are made up once a year. Apparatus that is needed or any large repair that is being contemplated should be sent to the Operating Superintendent for his consideration. Monthly figures on the cost of operation and maintenance should be kept by a clerical force, who also keep records of employment and check all payrolls against their records. Five or six clerks are needed in a large station.

Fueling of lighter than air ships presents an unusual problem, as it is desirable to keep the lift constant and using up of liquid fuel diminishes the load. In the Los Angeles, which uses gasoline, water of combustion in the exhaust gases is condensed and stored in tanks to maintain equilibrium. In the Graf Zeppelin, compressed Blau gas produced by cracking oil is used from its home port at Friedrichshafen. This gas has the same specific gravity as air so that, as it is used and replaced by air, no change is made in the weight of the ship. But, on the round the world cruise, it was necessary to find other fuel for other ports.

In the trip from Lakehurst, N. J., compressed ethane was successful. For Tokio, pyrofax was shipped in liquid form in cylinders by the Carbide and Chemicals Corp. from its West Virginia plant and mixed with hydrogen secured at Tokio. At Los Angeles, pyrofax, shipped there in tank cars, was again taken on but was mixed with California natural gas, to a specific gravity the same as air.

Savings effected in engine operation by using superheated steam result largely from decreased cylinder condensation. The amount of steam used is decreased approximately one per cent for each 10 deg. F. increase in superheat, although the first few degrees appear to be more important. Superheated steam requires special valves of the poppet or piston type in order to avoid warping and slicking. The upper temperature limit appears to be between 600 and 650 deg. F.

Pressure Effects *in* Pre-Combustion Oil Engines



INVESTIGATION OF PRESSURES IN HVID TYPE OIL ENGINE DISCLOSES CONDITIONS AFFECTING POWER AND EFFICIENCY. BY J. A. POLSON* AND H. E. DEGLER**

SEVERAL MAKES of solid-injection Diesel engines employ a pre-combustion chamber for injection and atomization of the fuel, the combustion of the atomized fuel being accomplished by means of the heat of compression, exactly as in the true Diesel engine. Figure 1 shows the cylinder head arrangement used in the Hvid type of oil engine. Operation of the cup, F, is based on the fact that every oil, no matter how heavy it may be, contains some light hydro-carbons that will vaporize or distill at a fairly low temperature. The explosion of these lighter parts of fuel in the pre-combustion chamber provides the means whereby the remainder of the fuel is injected into the engine cylinder in a finely atomized condition. A further matter of common knowledge is that the temperature of ignition of an oil is dependent upon the degree of atomization.

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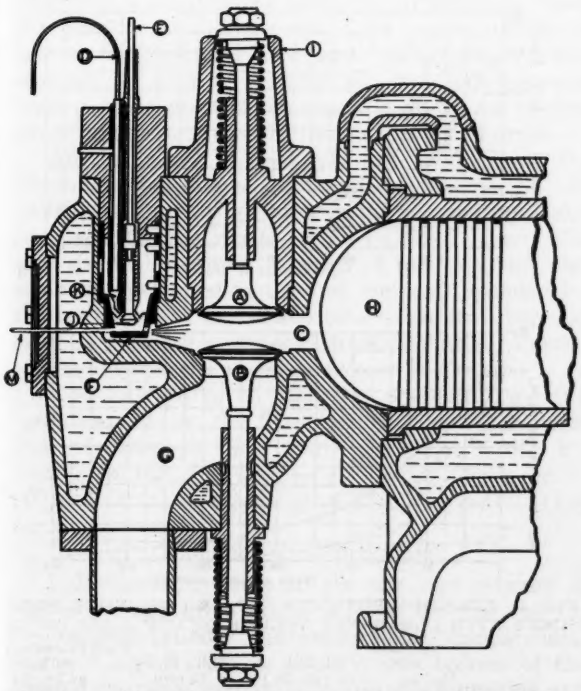

FIG. 1. SECTION THROUGH CYLINDER, COMBUSTION CHAMBER, VALVES AND FUEL CUP OF HVID OIL ENGINE

OPERATION OF ENGINE

Assume that the engine is on head end dead center with the piston as shown in Fig. 1 and that a charge of fuel and air is about to be admitted. As the piston H moves to the right on its suction stroke, fresh air for combustion of the fuel is admitted through the main air intake valve A. Previous to this, fuel oil had been pumped through pipe D to space K, which is above and to the left of fuel valve J, by means of a low-pressure fuel pump. Fuel valve J is mechanically opened soon after intake valve A has been opened and the fuel oil flows, partly by gravity and partly by inhalation, into the cup F. Air only is drawn into the cylinder. Fuel oil with a small amount of air is drawn into the fuel cup F and retained there. Air intake valve A and fuel valve EJ are held open almost to the end of the suction stroke. The amount of oil entering the fuel cup depends not upon the length of time that the valve is open but on the amount of fuel pumped by the variable stroke oil pump, which is controlled by a fly-ball governor through a floating link.

As the piston returns on the compression stroke with all valves closed, the pressure of the air in the cylinder and in the fuel-oil cup will increase to about 500 lb. per sq. in. at the end of the stroke. Air in the combustion chamber C at a high temperature of nearly 1000 deg. F. and under high pressure is forced into cup F through small holes near its bottom until the pressure in the cup is nearly equal to the pressure in the combustion chamber, see Fig. 2. The conditions in the cup are now most favorable to cracking the oil and, as the oil cracks, the lighter and more volatile components are detonated by the high temperature. The

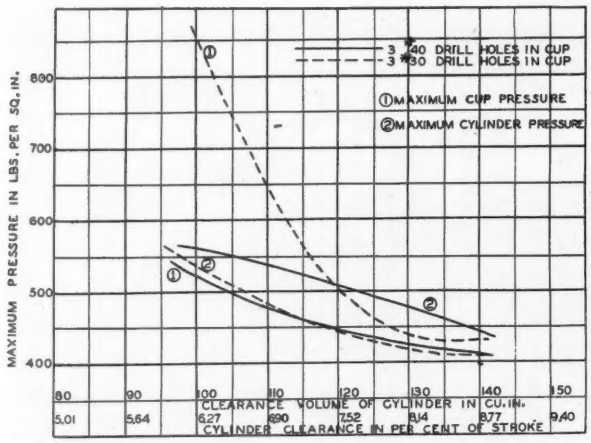
3 #40 DRILL HOLES IN CUP
3 #30 DRILL HOLES IN CUP
①MAXIMUM CUP PRESSURE
②MAXIMUM CYLINDER PRESSURE
MAXIMUM PRESSURE IN LBS. PER SQ. IN.
800
700
600
500
400
80 90 100 110 120 130 140 150
CLEARANCE VOLUME OF CYLINDER IN CU. IN.
5.01 5.64 6.27 6.90 7.52 8.14 8.77 9.40
CYLINDER CLEARANCE IN PER CENT OF STROKE

FIG. 2. CURVES SHOWING VARIATION IN CYLINDER AND CUP PRESSURES FOR VARYING CYLINDER CLEARANCE VOLUMES OF TWO SIZES OF HOLES IN FUEL CUP. ENGINE OPERATING AT 24.4 BR.HP. WITH CLEARANCE VOLUME OF CUP = 5.49 CU. IN.

resultant high pressure within the cup forces the rest of the oil out into the cylinder through the small holes near the bottom of the cup.

It is evident that the fuel cup performs two important functions: first, delays and therefore times the ignition; second, atomizes the fuel as it is forced through the holes and thereby aids combustion. The amount of fuel consumed in the cup per cycle is infinitesimal because only a small amount of air is present in the cup to support combustion. As the fuel in an atomized and vaporous state comes into contact with the heated air in the combustion space, rapid combustion takes place as the piston starts to the right on its expansion stroke. The fuel oil burns with an increase in temperature at nearly constant pressure and the gases expand and do work on the piston. All valves remain closed until near the end of the stroke when the exhaust valve B is opened and the gases begin to escape to the outside air through the exhaust port G. During the return or exhaust stroke, the exhaust valve B remains open until near the end of the stroke, so that as much as possible of the burned gases may escape.

Method of Conducting Tests

Arrangement for tests of the 35-hp. 10⅝ by 18-in. Hvid type engine is shown in the head piece of this article. One indicator connection, made to the cylinder head, was located in the area concentric to and back of the fuel cup and a second one was made to the fuel cup through the head end of the engine, as shown at M, Fig. 1. Cylinder clearance volume was determined by filling the clearance up to the indicator piston with a measured quantity of oil, when the piston was on head end center, with valves closed and fuel cup in place. Fuel cup clearance volume was determined in place by filling this space in a similar way. The size of holes in the fuel cup ranged for different tests from No. 40 (0.098 in. dia.) to No. 20 (0.161 in dia.) drill holes. Three holes of equal size located near the bottom of the fuel cup were used for all tests.

Cylinder clearance volume was varied in the usual way by changing spacer plates on the connecting rod. Pre-combustion chamber volume was varied by changing cups and also the size of holes in the fuel cup by re-drilling. The internal surface of the cylinder clearance space, with a ⅛-in. spacer between the connecting rod and crankpin box, was calculated to be 294 sq. in. and the total internal combustion surface as 895 sq. in.

For the preliminary series of tests made on the engine, piston type gas engine indicators were used to take simultaneous indicator cards of the cylinder pressure and of the fuel cup pressure. Test data were collected for a selected size of hole in the fuel cup under varying clearance volumes. The outgoing temperature of the jacket cooling water was kept nearly constant at about 140 deg. F. for all tests. The holes in the fuel cup were then re-drilled and a similar set of data obtained. It will be noted, by referring to Fig. 2 that in one case the maximum cylinder pressures are greater

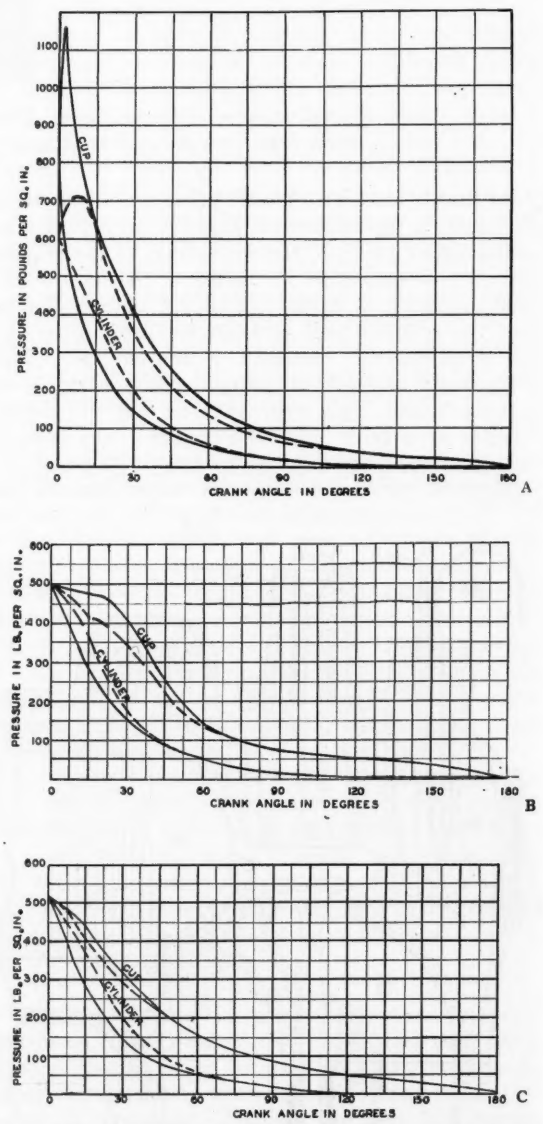

FIG. 3. RELATION BETWEEN CUP AND CYLINDER PRESSURES WITH CLEARANCE VOLUME OF CUP = 5.55 CU. IN.

	Br.hp.	Cl. Vol. cyl. (cu. in.)	Drill holes in cup	Fuel Consump. lb. per br.hp.-hr.
A.	24.77	107.1	3—No. 20	0.82
B.	24.6	118.2	3—No. 20	0.76
C.	23.6	118.2	3—No. 25	0.792

than the maximum cup pressures, while in the other the reverse is shown. This is due to the difference in the size of the holes in the cups.

Diaphragm Indicator Used for Later Tests

Preliminary tests and better running conditions of the engine showed that the use of smaller than No. 30 (0.1285 in. dia.) drilled holes in the cup was unsatisfactory. Realizing that the size of the fuel cup holes was approaching that required for best operation, the piston type indicators were replaced with U. S. Bureau of Standards diaphragm indicators. This change was made to insure more accurate results and to avoid the errors of piston type indicators due to inertia, friction, leakage, and back lash in moving parts.

Fundamentally, the principles of the diaphragm pressure indicator are, balancing of the cylinder pressure against a measured air pressure on opposite sides

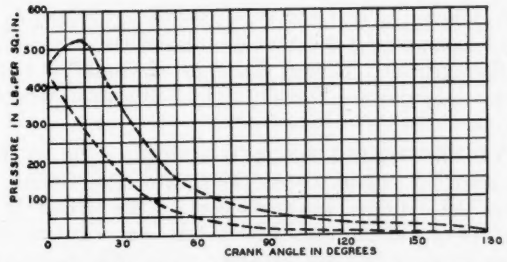

FIG. 4. TYPICAL CYLINDER PRESSURE DIAGRAM AT 25 BR.-HP. WITH 3—NO. 24 DRILL HOLES IN CUP, CLEARANCE VOLUME OF CUP = 5 CU. IN. AND CLEARANCE VOLUME OF CYLINDER = 129.3 CU. IN. FUEL CONSUMPTION 0.615 LB. PER BR.HP.-HR.

of a steel diaphragm of negligible stiffness and indication by means of a timing device of the instant at which equality of pressure occurs. Once in each cycle the pressure on the lower side of the diaphragm (cylinder pressure) is equal to the measured air pressure, which the operator applies through ⅛-in. copper tubing to the space above the diaphragm. Diagrams are constructed by plotting cylinder and fuel cup pressures from point to point in the engine cycle, giving at each point the average pressure from a number of cycles.

Another series of tests was then made using the diaphragm indicators, beginning with three No. 30 (0.1285 in. dia.) drilled holes in the cup and gradually increasing the hole size to No. 20 (0.1610 in. dia.). For each size of holes used, a record of the load, fuel consumption, pressures in the fuel cup and cylinder for the various crank angles and other correlated data was made for varying cylinder clearance volumes. Typical results of this series of tests are shown in Fig. 2.

Fuel oil used in all tests was Standard Fuel Oil, manufactured by the Standard Oil Co. of Indiana. Degrees Baumé = 38, Gravity = 0.833 at 88 deg. F.; Distillation test, first drop = 410 deg. F., dry point = 600 deg. F. and heat value of fuel was 18,500 B.t.u. per lb.

Results and Conclusions

1. Maximum pressure in the cup and cylinder is highest for any given size of holes in the fuel cup for the smallest cylinder clearance volume, compare diagrams A and B, Fig. 3. This is true because of the lowered clearance volume, of increased compression and resulting combustion pressures.

2. Fuel consumption per horsepower per hour for a given load on the engine decreased as the size of the holes in the fuel cup was increased, see Fig. 5. The fuel can be forced out of the cup more easily and rapidly with the larger holes, thus igniting and burning the cylinder charge earlier and more rapidly.

3. If the size of the holes in the fuel cup is increased, the cylinder clearance volume should also be increased, for better fuel economy, see Fig. 5. Thus with No. 40 holes, the best cylinder clearance is 6 per cent; while with No. 30 holes the best clearance is 6.7 per cent and for No. 24 holes the best clearances is 8 per cent. With a small cylinder clearance and small holes in the fuel cup, the fuel enters the cylinder slowly, hence high compression pressure is required for a longer time in order to ignite the fuel properly; this effect is produced by a relatively small clearance volume.

4. The maximum cylinder pressure exceeds the maximum cup pressure, at any cylinder clearance volume, for holes in the fuel cup smaller than No. 30, see Fig. 2. Small holes in the cup retard the flow of air into the cup and the pressure produced is not as high as when the holes are larger and a better combustible mixture is formed.

Pressure Difference Insures Rapid Fuel Spray

5. For No. 30 and larger holes in the fuel cup, the maximum cup pressure exceeds the maximum cylinder pressure, Figs. 2, 3A and 3B. This is a desirable condition, inasmuch as excess of the cup-cylinder pressure insures the more rapid ejection of the fuel from the cup. Complete combustion is effected in the cylinder earlier in the stroke, thus resulting in better fuel economy.

6. Maximum cup and cylinder pressures occur just after the piston has passed the head end dead center on the expansion stroke, see Figs. 3 and 4.

7. The holes in the fuel cup were parallel to each other and to the bottom of the cup. The bottom of the holes was slightly above the bottom of the cup, thus accomplishing better scavenging.

8. Maximum mean effective pressure is required in order to obtain maximum power and since m.e.p. depends largely upon the compression pressure, the highest compression pressure obtainable is generally desired.

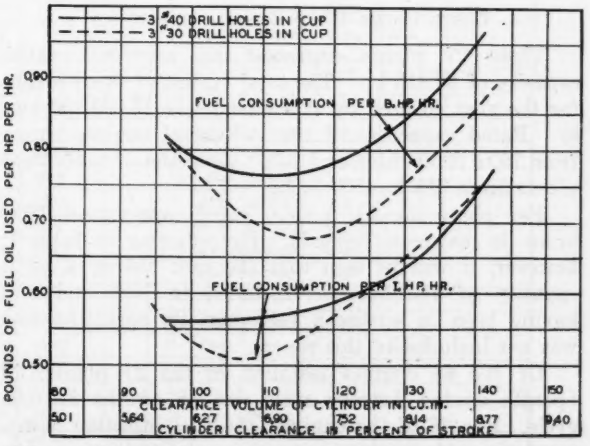

FIG. 5. RELATION OF FUEL CONSUMPTION TO CYLINDER CLEARANCE VOLUME FOR TWO CONDITIONS OF DRILLED HOLES IN CUP

To prevent so-called pre-ignition with its attendant disagreeable and harmful pounding and increased fuel consumption it becomes necessary to use a relatively low compression pressure when burning fuel oil, and this lowers the m.e.p. and power output. The engine tested, with a clearance volume of 129.3 cu. in. (8 per cent) and No. 25 holes in the fuel cup gives a maximum compression pressure of about 500 lb. per sq. in. at 25 brake hp., for best operation and fuel consumption. See Fig. 4.

9. So-called pre-ignition knock, which occurs when using too high a compression pressure may be caused not by pre-ignition but probably by small detonations after ignition has occurred and the piston has started on the expansion stroke. When this knock occurred during the tests, the pressures caused thereby were always found by the diaphragm indicator to occur after the piston had begun its expansion stroke. These delayed detonations are due to the fact that the fuel used is of a complex chemical make-up and, after ignition has started, the conditions are most favorable for cracking it.

10. Best fuel consumption for this engine was secured with three No. 24 drill holes in the fuel cup, a cylinder clearance of 8 per cent and no indicator connection to the fuel cup. For this condition, the maximum pressure at 32 brake hp. was about 600 lb. per sq. in. and the fuel consumption, 0.60 lb. per brake hp. per hour.

11. Results of the final test showed that the piped indicator connection to the fuel cup used in the previous tests had a decided effect upon the maximum power the engine would develop and also upon the fuel economy. An explanation for this is that, when the preliminary explosion occurs in the fuel cup, some of the fuel is forced into the fuel cup indicator connection; then, as the piston moves away from the head end, the fuel will be forced back or drawn into the cup. In this way, much of it re-enters the cup and then goes into the cylinder, thus being burned inefficiently and ineffectively after the main cylinder explosion has occurred A correlated explanation is that, if several tubes were used in place of the fuel cup, the purpose of the fuel cup and holes would be defeated, in that the proper utilization of the air-fuel mixture and compression pressures would be impossible.

Burning Is Approximately at Constant Pressure

12. Fuel combustion in the pre-combustion chamber and cylinder of this engine, as shown by Figs. 3A, 3B and 4, is an almost constant pressure burning, especially in the cylinder. Hence, this type of engine is similar to a solid-injection Diesel type of internal-combustion engine.

13. This type of engine is a simple form of solid-injection oil engine; it employs automatic timing, because the cylinder pressures control the timing of the fuel spray and the fuel is heated by compression before being sprayed into the cylinder. The only objection is that the combustion is not mechanically timed and it is probably a little late and slow.

Diesel Engine Power Costs for 1927-1928

Analysis of Diesel Power Costs Indicates Trend Toward Further Plant Refinement and Need of Standardization of Cost Methods. By Franz Eder*

DIESEL ENGINE POWER costs, based upon data returned by 27 widely distributed plants having rated capacities of 100 hp. or over, in response to a questionnaire sent out by the sub-committee on oil engine power costs of the Oil and Gas Power Division of the A. S. M. E. were reported principally on Tables I and II.

Costs Cover Wide Range Conditions

These 27 plants represent an aggregate rated capacity of 38,315 hp. The total output of these plants for the year covered by this report was 75,395,250 kw-hr. Rated capacities of the individual engines range from 75 to 2250 br.hp. and rated capacities of individual plants from 315 to 4500 br.hp.

For plant No. 14, a total rated capacity of 1200 br.hp. is shown in Table II. By referring to Table I, however, it will be seen that the unit having a rated capacity of 750 hp. was installed in 1928 and, not having been in service a full year, its operating cost was not included in this report.

Of the 68 engines installed in the 27 plants, 30 operate on the 2-stroke cycle and 38 on the 4-stroke cycle. For 26 of the engines, the fuel injection is airless while for 42 it is by air injection. All of the engines are of the vertical type, direct connected to electric generators.

Running engine capacity factor, per cent; column 16, Table I, is (output of engine in kw-hr. per yr. $\times$ 100) $\div$ (rated kw. $\times$ engine running hr. per yr.). Running capacity factor, per cent, column 9, Table II, is (total output in kw-hr. $\times$ 100) $\div$ (rated kw. of unit No. 1 $\times$ hr. run by unit No. 1 + rated kw. of unit No. 2 $\times$ hr. run by unit No. 2, etc.). Annual plant load factor, per cent, column 8, Table II, is (total output kw-hr. $\times$ 100) $\div$ (8760 $\times$ peak load carried by plant in kw.). Plant service factor, per cent, column 10, Table II, is (rated kw-hr. run $\times$ 100) $\div$ (rated kw-hr. possible during year). The equivalent kilowatts shown in column 4, Table II, is only approximate.

Fuel Oil Costs

Cost of fuel oil ranges from 2.44 to 6.74 cents per gallon. Averages are given where prices vary. The amounts of fuel oil in pounds used per kilowatt-hour range from 0.62 to 1.288. Cost of fuel oil per kilowatt-hour ranges from 2.61 to 13.8 mills.

Cost of lubricating oil ranges from 25.6 to 80.5 cents per gallon. Averages are given where prices vary.

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Rated brake horsepower-hours per gallon of lubricating oil range from 16,650 to 400. Cost of lubricating oil per kilowatt-hour ranges from 0.16 to 1.99 mills.

All attendance shifts are 8 hr. and there are three a day. Supplies in plants 2, 10 and 11 include rags and kerosene. In plant 7, cooling water cost is included. Repairs include labor for repairs as well as material used. Plants 15, 22 and 23 have a yearly maintenance guarantee which is listed in the tabulation under repairs. Cost of supplies per kilowatt-hour ranged from 0 to 18.7 mills and cost of repairs per kilowatt-hour from 0 to 2.46 mills.

Total operating costs per kilowatt-hour range from 4.81 to 119 mills. Weighted average values of cost in

TABLE I. SUMMARY OF DIESEL ENGINE DATA

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Plant Number	Unit Number	Name of Manufacturer	2or4 Stroke Cycle	Air or Airless Injection	Rated Brake H.P.	Number of Cylinders	Diameter of Cylinders	Stroke	Rated R.P.M.	Year in which Engine Started	Type of Drive	Connected to—	Running Hours per Yr.	Kw.Hrs. Output per Yr.	Running Engine Load Factor	Number of Enforced Shut Downs	Total Duration of such Shut Downs
1	a	Nordberg Manufacturing Co.	2	Air	2250	4	28"	44"	120	1927	Direct Connected	Generator	8189	10562300	85.0	13	17.8 Hrs.
	b	"	2	"	2250	4	28"	44"	120	1926	"	"	8255	10626800	86.0	9	4.8 "
2	a	Fulton Iron Works	4	"	1150	6	23"	29"	166.6	1925	"	"	6730	5021320	94.5	28	81.0 "
	b	"	4	"	1150	6	23"	29"	166.6	1925	"	"	6670	4966520	94.3	45	146.0 "
	c	"	4	"	1150	6	23"	29"	166.6	1925	"	"	6610	4943870	92.9	28	70.0 "
3	a	DeLaVergne	4	Airless	400	6	14.5	18	277	1923	"	"	735	280000	13.0	None	
	b	McIntosh Seymour	4	Air	800	8	17	24	200	1924	"	"	4015	1058000	43.9	2	
	c	"	4	"	800	8	17	24	200	1926	"	"	4000	1150000	48.1	2	
	d	DeLaVergne	4	Airless	1125	6	22	30	180	1927	"	"	2920	941000	57.8	None	
4	a	Fairbanks Morse & Co.	2	"	200	4			257	1922	"	"			80.0	6	0.2
	b	"	2	"	300	6			257	1923	"	"			80.0	3	24
	c	"	2	"	360	6			257	1926	"	"			90.0	2	0.2
	d	"	2	"	720	6			257	1927	"	"			90.0	None	
	e	"	2	"	720	6			257	1927	"	"			90.0	"	
5	a	Fairbanks Morse Co.	2	Air	720					1916	"	"					
	b	"	2	"	720					1916	"	"					
	c	"	2	"	720					1916	"	"					
6	a	"	2	Airless	300					1926	"	"					
	b	Worthington Pump & Mach. Co.	4	Air	600		17	25		1926	"	"					
	c	"	4	"	600		17	25		1926	"	"					
	d	"	4	"	600		17	25		1926	"	"					
7	a	Beaumer Gas Engine Co.	4	Airless	350	6	11.5	16	277	1923	"	"	5248	783066	56.0	None	
	b	"	4	"	350	6	11.5	16	277	1923	"	"	4409	648066	55.0	"	
	c	"	4	"	350	6	11.5	16	277	1923	"	"	4826	736066	58.0	"	
	d	"	4	"	800	6	16	22	250	1927	"	"	4330	1358700	50.0	"	
8	a	McIntosh Seymour	4	Air	400	4	16.5	24	200	1921	"	"	3144	324000	40.0	"	
	b	Worthington Pump & Mach. Co.	4	"	560	3	22.5	22.5	225	1922	"	"	2520	498000	50.0	"	
	c	"	4	"	600	6	17	25	200	1926	"	"	5436	1176000	55.0	"	
9	a	McIntosh Seymour	4	"	750	4	23	32	150	1924	"	"	4000				
	b	"	4	"	750	4	23	32	150	1924	"	"	4000				
10	a	Fulton Iron Works	4	"	750	4	22	29	166.6	1924	"	"	2399	904200	75.0	"	
	b	Busch Sulzer	2	"	750	4	17	27	176.5	1925	"	"	5672	2097580	71.0	9	32.6 "
11	a	Fulton Iron Works	4	"	750	4	22	29	166.6	1924	"	"	908	319410	67.5	3	12.2 "
	b	McIntosh Seymour	4	"	600	6	16.5	24	200	1925	"	"	3296	1190420	87.7	4	18 "
12	a	Worthington Pump & Mach. Co.	2	"	450	6	15.25	16	275	1926	"	"	4812	1010000	62.5	None	
	b	"	2	"	450	6	15.25	16	275	1926	"	"	4973	1039900	63.5	"	
	c	"	2	"	450	6	15.25	16	275	1926	"	"	5139	1009000	58.5	"	
13	a	Fulton Iron Works	4	"	265	4	13.5	19.5	257		"	"	5466	707800	65.0	"	
	b	"	4	"	200	3	23	29.5	257		"	"	1726	293200	90.0	1	.2 "
	c	"	4	"	750	4	23	29.5	164		"	"	2394	714600	53.0	None	
14	a	Wardberg Manufacturing Co.	2	"	450	3	16.75	22	225	1926	"	"	8000	869500	36.0	"	
	b	"	2	"	750	4	16.75	22	240	1928	"	"					
15	a	McIntosh & Seymour	4	"	600	6	17	24.5	200	1926	"	"	4320	600000	32.0	1	
	b	Fulton Iron Works	4	"	600	6	17	24.5	200	1926	"	"	4320	600000	32.0	1	
20	a	DeLaVergne	4	"	300	3	17	24	225	1925	"	"	1500	190000	53.0	None	
	b	"	4	"	300	3	17	24	225	1925	"	"	1600	190000	53.0	"	
21	a	Worthington Pump & Mach. Co.	2	Air	300	4	15.25	16	275	1925	"	"	4320	261250	270	"	
	b	"	2	"	300	4	15.25	16	275	1925	"	"	4440	432175	43.5	"	
22	a	Fulton Iron Works	4	"	300	3	17	24.5	200	1927	"	"	4320	360000	37.2	1	
	b	"	4	"	300	3	17	24.5	200	1927	"	"	4320	360000	37.2	1	
23	a	"	4	"	300	3	17	24.5	200	1926	"	"	4320	450000	46.5	1	
	b	"	4	"	300	3	17	24.5	200	1926	"	"	4320	450000	46.5	1	
24	a	DeLaVergne	2	Airless	200	3	14.5	18	277	1925	"	"	5640			None	
	b	"	2	"	200	3	14.5	18	277	1925	"	"	5640			"	
25	a	Fairbanks Morse Co.	2	"	360					1925	"	"					
26	a	Ingersoll Rand Co.	4	"	330	3	17.75	22	225	1927	"	"	2400	270000	45.7		
27	a	Worthington Pump & Mach. Co.	2	"	240					1926	"	"					
	b	Fairbanks Morse Co.	2	"	75					1926	"	"					

mills per kilowatt-hour are shown in Table III. Plants 15, 20, 22 and 23 have two engines, each running 180 days, the other one being used as a standby. Plants 15, 22 and 23 generate power for pumping water for a city and for cold storage plants. Plant 25 apparently operated only a short time during the year. Data

TABLE III. WEIGHTED AVERAGE VALUES OF COST IN MILLS PER KILOWATT-HOUR

Fuel oil	4.2
Lubricating oil	0.43
Attendance	2.82
Supplies	0.63
Repairs	0.66
Total Operating Cost	8.74

TABLE IV FIXED CHARGES

Taxes and Insurance Per cent	Number of plants reported	Annual interest charged Per cent	Number of plants reported	Fair life of plant Number of years	Plants
0	2 (1)	4½	2	10	4
1	2	5½	3	20 (2)	15
1½	1	6	3	25 (3)	3
2	8	7	8		
5	1				

(1) One of the plants reports no taxes; insurance cost being carried in plant equipment. (2) Another plant reports fair life of plant from 20 to 25 yr. while another (3) reports fair life of building, 50 yr. and of equipment, 25 yr.

which will permit greater reliability of comparison with other prime movers. To accomplish this object, more

TABLE II. SUMMARY OF DIESEL PLANT OPERATING COSTS

1	2	3	4	5	6	7	8	9	10	11		12	13	14	15	16	17	18	19	20					
Plant Number	Number Engines in Plant	Total Br-HP Installed	Equivalent Kw. Installed	Annual Output of Plant (Kw.-Hrs.)	Engine Hours Run	Peak Load on Plant During year (Kw.)	Annual Plant Load Factor %	Running Plant Capacity Factor %	Service Factor %	Hours Run Per Day Maximum	Minimum	Cost Per Gallon Fuel Oil (Cents)	Cost Per Gallon Lubricating Oil (Cents)	Fuel Oil Used per Kw.-Hr (Pounds)	Lub. Oil Used per Kw.-Hr (Gallons)	Rated Br-HP per Gal. of Lub. Oil	Attendance No. per Shift (Shifts per 24 Hrs.)	Kind of Fuel Oil Used Average (Direct-Indirect)	Cooling System (Open or Closed) (Raw or Softened)	Operating Cost in Mills per Kw.-Hr					
																				Fuel Oil	Lub. Oil	Attendance	Supplies	Repairs	Total
1	2	4500	3880	21 189 100	16,944	3200	76.4	86.0	94.0	24	24	4.75	71.5	0.67	.000265	7750	3	15°B.	C S	4.08	0.16	0.94	0.11	0.64	5.93
2	3	3450	2400	14 833 310	20,010	2300	73.6	96.5	76.5	24	8	3.43	61.0	0.654	.000360	2744	3	26°B.	O R	2.78	0.14	0.99	0.25	0.56	4.81
3	4	3125	2100	3 351 000	11,670	1150	34.0	51.0	54.4	24	24	3.20	49.0	0.6395	.000430	4570	2	22°-28°B.	C R	4.35	0.32	4.02	1.47	1.81	11.97
4	3	2300	1535	5 252 000	17,500	800	38.0			24	24	5.00	54.0	0.689	.001040	2350	3	26°-28°A	O-S	4.84	0.34	1.92	1.45		8.77
5	3	2160	1440	401 150						24	24	5.71	63.9	1.2	.002500	460			C S	9.25	1.32	2.44	0.99		14.00
6	4	2100	1400	1 470 500						24	24	3.84	68.5	0.78	.001210	1100			C S	6.10	0.79	2.80	2.07		11.86
7	4	1880	1230	2 886 200	18,807	1,000	33.0	50.0	53.5	24	24	6.10	42.0	0.682	.001420	1710	2	36-40°B.	C S	5.37	0.80	3.22	1.40	1.06	11.85
8	3	1360	1040	1 998 200	11,100	600	38.5	50.6	44.0	24	24	3.00	58.0	0.7	.001220	2450	2	24°G	O S	3.00	0.71	5.13	0.50	2.04	9.38
9	2	1500	1000	4 831 200	8,000	1200	46.0			24	10	3.30	80.5	0.64	.000360	3420	1	23°-27°B	O R	2.82	0.29	2.18	0.88	0.88	6.01
10	2	1500	1000	3 001 790	8,071			79.5	46.0	24	11	2.92	56.0	0.74	.001820	1112	2	26°B	O R	2.97	0.98	2.48	0.18	1.40	8.01
11	2	1350	900	1 503 830	4,198	415	36.6	85.0	33.6	24	4	2.46	25.6	0.681	.001340	1317	2	26°B	O R	2.61	0.36	3.16	0.21	1.00	7.38
12	3	1350	900	3 078 700	16,924	435	81.5	69.0	57.0	24		4.00	27.0	0.688	.000610	3250	2	Gas Oil	O S	4.81	0.18	98.1	1.11	0.21	10.40
13	3	1215	810	1 655 400	9,586	450	41.9	69.0	34.0	24	24	5.80	49.0	0.62	.001070	2040	3	Distillate	O R	6.24	0.52	5.74	1.52	0.17	14.20
14	2	1200	800	869 500	9,000	340	29.2	36.0	91.5	24		6.30	59.5	1.0	.000900	4600	3	24°-26°B	O R	8.01	0.934	4.16	0	0	14.50
15	2	1200	800	1 200 000	9,640	550	25.0	35.0	49.0	24	24	5.25	37.5	0.78	.001670	2593		24°G	C R	5.7	0.625	9.2		0.5	16.70
16	3	1200	800	1 203 000						24	24	5.69	53.6		.001180	.750			C S	6.72	0.91	3.8	2.92		14.35
17	2	1200	800	896 200						24	24	8.93	60.5		.001800	1,350			C S	8.42	0.385	6.18	2.22		17.41
18	2	1050	700	1 475 458						24	24	5.33	69.2		.001610	850			C S	6.1	1.03	2.55	0.96		10.66
19	3	700	660	270 140						24	24	5.68	66.1		.001940	700			C S	16.25	1.32	8.44	9.85		28.0
20	2	600	400	360 000	3200	145	28.3	34.2	18.3	24	4	6.40	63.0	0.68	.000920	2890	2	32°-36°G	C R	7.4	0.58	4.38	0.106	0.093	14.76
21	2	600	400	693 425	8,760	200	40.0	39.5	50.0	24		2.44	53.2	1.12	.002710	1397	2	Gas Oil	O S	3.03	1.45	18.0	1.29	2.46	27.0
22	2	600	400	720 000	8,640	210	39.1	41.7	49.3	24	24	5.00	31.5	0.95	.001800	2000		22°G.	C R	5.55	0.675	6.66		1.00	13.9
23	2	600	400	800 000	8,640	230	45.0	52.1	49.3	24	24	5.00	31.5	0.75	.001450	2000		26°G.	C R	4.46	0.541	8.66		0.8	14.4
24	2	400	265	622 000	11,280	320	22.2	41.0	64.3	24	3	4.00	62.0	0.82	.000960	3760	3	32°-36°B.		7.69	4.6	6.90	0.96		12.76
25	1	360	240	35 200						24		5.72			.000400	3,200			C R	7.6		9.25	18.7		1180
26	1	330	220	270 000	2,400			53.0	27.4	12.5		5.00	46.0	0.71	.001380	2130	1	26°-28°B.	O R	4.71	0.65	8.45	0	1.02	14.8
27	2	315	210	187 231						24		6.74	80.0		.002890	500			C R	13.8	1.19	12.6	13.6		42.0

concerning plants 16 to 19 inclusive were omitted from Table I because only meager data were presented at the meeting.

Fixed Charges Show Wide Variation

Fixed charges in mills per kilowatt-hour reported by different plants are:

Plant No.	Fixed Charges
2	2.3
3	9.1
4	1.4
7	2.6
10	4.7
11	8.6
12	1.5
13	10.7
14	7.5
20	15.9
24	8.4

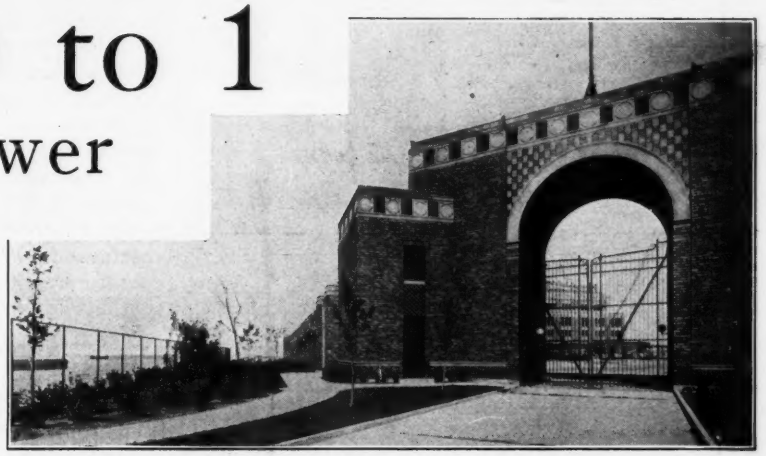
This was the first attempt of the A. S. M. E. to collect oil engine costs. Its importance rests, not so much with the actual data assembled as in the step which has been taken to gather dependable cost data complete coöperation with oil engine builders, not only in furnishing data but in submitting it in a standard form, is essential in the future.

One of the high-pressure boiler designs which has been enjoying considerable success in Europe is known as the Loeffler or steam pumping process. This boiler consists of a drum of water or vaporizer into which is injected, through a series of jets, highly superheated steam.

In passing through the water, the superheated steam gives up its superheater to the water and vaporizes some of it. Saturated steam from the drum is circulated by a steam motor or turbine-driven pumps, through superheating coils in the furnace. Some of the steam from these coils goes to the prime mover and part is recirculated back to the vaporizer.

In this system, only the superheater tubes are subjected to the fire, and scale deposited in the vaporizer drum acts as additional insulation to prevent heat loss. In case some irregularity causes the superheater to heat above a safe temperature, expansion of a straight section of the tube opens a relief valve, causing steam circulation and at the same time cuts off the fuel firing.

200,000 to 1 In This Power Plant Arena



First Unit for State Line Plant, Designed for Base Load Operation, is Completed

FOOTBALL STADIUMS to accommodate 100,000 have come to dot our collegiate landscape in all sections of the country. But through this gateway, which might serve as an entrance to a university campus, one sees an attractive structure for housing 200,000, not cheering holiday enthusiasts but steady everyday kilowatts. For this is the home of State Line plant, a base load station first described in the June 15, 1928 issue of Power Plant Engineering. It is owned jointly, either directly or indirectly through subsidiaries, by the Commonwealth Edison Co., the Public Service Co. of Northern Illinois, the Northern Indiana Public Service Co. and the Interstate Public Service Co., power being supplied to each according to the interest which it owns.

Situated on made ground on the line between Illinois and Indiana at the foot of Lake Michigan, the plant extends 1200 ft. into the lake. The present equipment has a capacity of 208,000 kw. or 248,000 kv-a. in a single three-element generating unit, served by eight condensers, six boilers and corresponding auxiliaries.

Condensing water is pumped from a forebay along the shore and returns to the lake by gravity overflow from the tops of the vertical condensers. Coal is received by rail, passes to storage or through a breaker and to bunkers, while ash is sluiced to an ash house and delivered by clam shell buckets to railroad cars.

Current passes beneath the operating room, located at the front of the station, to three outdoor bus and switch structures shown in Fig. 12, thence to the outgoing lines.

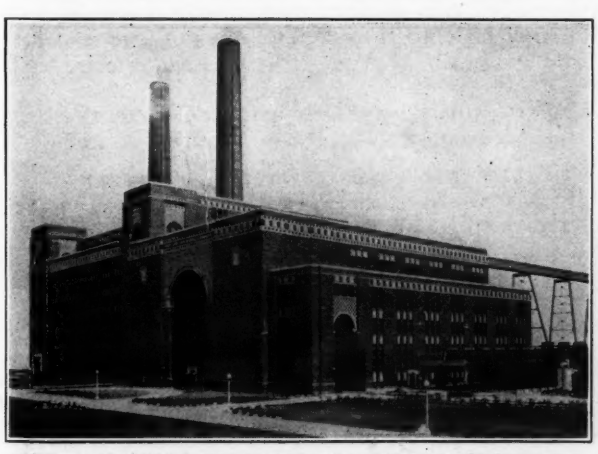


FIG. 1. DECORATIVE DOORWAYS AND CORNICES EXPRESS THE MODERN NOTE EXEMPLIFIED BY THE WORLD'S LARGEST GENERATING UNIT WITHIN

Location of the plant is shown in Fig. 2, with the convenience of cooling water and fuel tracks. The boiler house is next the shore, boilers running lengthwise of the room back to back in rows, with coal bunkers above. Along the land side of the boiler room is the turbine room with operating switchhouse beyond and outdoor switchyard adjoining. Ash handling equipment and unit pulverizers are below the boiler room floor level, forced and induced draft fans are above the boilers and in the top of the boiler house is a cross system of belt conveyors for distributing coal to the bunkers.

Between boiler room and turbine room is a section which accommodates steam headers, separators, switching for boiler room auxiliaries and main conveyor.

The three elements of the turbine unit are placed parallel, the high-pressure element between the duplicate double-flow low-pressure elements with vertical condensers at the ends of those elements. The generator of each element is separately controlled through its own switch and bus structure but all feed to the same main high-tension system. To serve the turbines and condensers, a 150-t. traveling crane is provided.

Coal Handling

Coal comes by railroad. On the track is a car dumper, 60 ft. long and capable of handling 20 cars an hour, which delivers to a belt conveyor leading to the breaker house, or to storage which is of underwater type. Spreading and reclaiming are by means of a drag scraper, the general appearance of the system being shown in Fig. 3.

From the breaker, a belt conveyor at right angles leads to the boiler house and delivers to cross conveyors, one over each row of coal bunkers. The coal feeds by gravity through scales to the unit pulverizers and from them is blown direct to the furnaces. Two mills are used for each boiler, each mill supplying four burners in each half of the furnace to insure uniformity of fuel supply and uniform flame distribution in case one mill is inoperative for any reason. An exhauster takes the powdered fuel from each mill and blows it to the burners.

Ash drops to hoppers below the boilers, thence to sluices which take it to an ash pit below the ash house

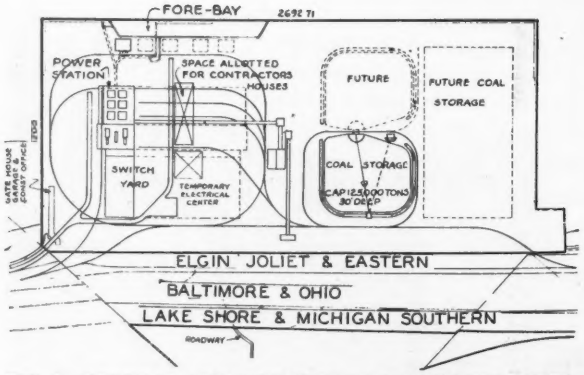


FIG. 2. GENERAL ARRANGEMENT OF STATE LINE, SHOWING SOME OF THE RAILROAD FACILITIES, COAL STORAGE SPACE AND PROVISION FOR EXPANSION

whence it is removed to cars by a crane carrying a clam-shell bucket.

Steam Making

Using the steaming economizer and the well-known single pass, cross drum design of boiler No. 22 at Calumet Station, each of the six steam generating units is capable of supplying a maximum of 450,000 lb. per hr. of 650-lb. gage, 750-deg. steam. Two 20-t., 70-in. unit mills of the air separation type and eight Calumet type burners are used with each boiler, coal being fed by gravity from overhead bunkers through individual automatic coal scales and feeders. Exhausters are located near the feeders for their respective mills on the operating floor above the mill and immediately in front of the burners.

Gases make a single pass upward over the tubes of the boiler and superheater, downward through the economizer, upward through the air heater to the induced draft fans and out through dust collectors to the stack. Two double-inlet, vane-control, 60,000-c.f.m. forced draft fans and two 110,000-c.f.m. induced draft fans are furnished for each boiler. Three different models of dust collectors are being tried and it is expected soon to install a fourth.

Furnaces, Large in Proportion to Boiler Heating Surfaces, Are Completely Water-Cooled

Designed for a maximum of 800 lb. per sq. in., the boilers will be operated at 650 lb. gage. The seamless forged steel drums are 52 in. in diameter and 3¼ in. thick while the heating surface of 10,294 sq. ft. is arranged eight tubes high, the lower three rows spaced wide to form a slag screen.

Furnaces are completely water cooled, partially by bare blocks and partially with refractory covered tubes on the side walls and bare blocks on the ash pit floor, the total water-cooling surface being 4441 sq. ft. The furnace volume of 22,500 cu. ft. is large when considered in relation to the relatively small boiler heating surface of 10,294 sq. ft., although in line with contemporary practice when considered in relation to the steam output of 450,000 lb. per hr.

Superheaters, Economizers and Air Heaters

Superheater surface, designed to give a total steam temperature of 750 deg. F. totals 7200 sq. ft.; the loop type counterflow economizer connected to the boiler so as to take care of steaming has a surface of 19,820 sq. ft. while the single pass, counterflow tubular air heater with inclined tube sheets has a surface of 56,401 sq. ft.

Including the economizer, the water heating surface totals 34,555 sq. ft. which at an evaporation of 450,000 lb. per hr. gives an average of 13 lb. of steam per sq. ft. of heating surface. Considerable steam is made in the economizer but considering only the water wall and boiler surface of 14,735 sq. ft., the evaporation per square foot is over 30 lb.

All boilers are automatically controlled and, at a load of 150,000 kw., with a steam flow of 1,454,400 lb. of steam per hr. to the turbine room, the boiler room efficiency is in the neighborhood of 85 per cent.

Turbine Consists of Three Elements

Although the boiler room represents the latest practice in boiler and furnace design, the unusual feature of the station is the 208,000 turbine unit, a three-element unit operated as a two-unit machine and consisting of one high pressure 76,000-kw. generator and two 62,000-kw., low-pressure generators, giving a total generating capacity of 200,000 kw., the additional 8000 kw. consisting of two 4000 kw. shaft generators, one on each low-pressure machine. All elements operate at 1800 r.p.m.

Cross section of the high-pressure turbine is shown in Fig. 5A, and the low-pressure turbine in Fig. 5B. The high-pressure turbine receives steam at 645 lb. abs.,

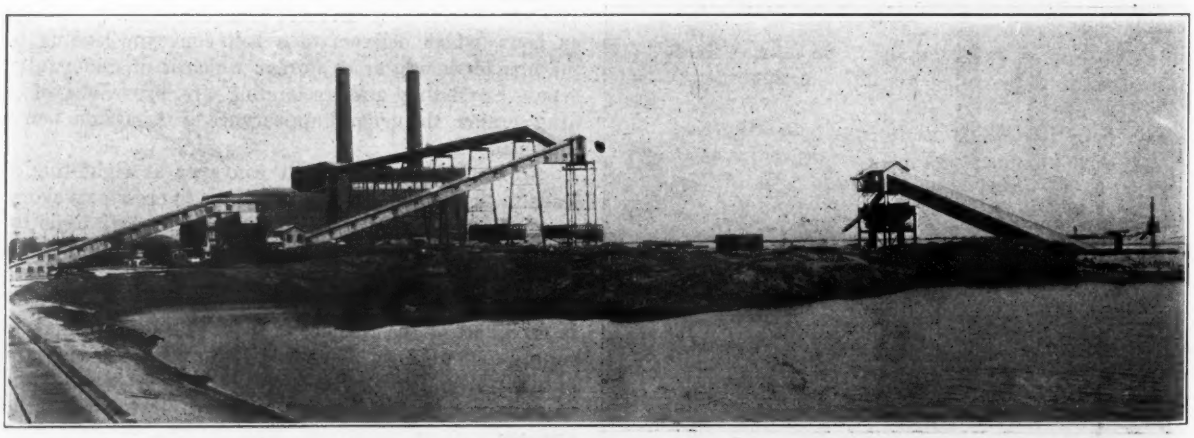


FIG. 3. COAL, STORED UNDER WATER, IS HANDLED BY DRAG SCRAPER. CONVEYOR AT LEFT CARRIES COAL FROM CAR DUMPER TO COAL BREAKER, FROM WHICH ANOTHER CONVEYOR TAKES IT TO BOILER HOUSE

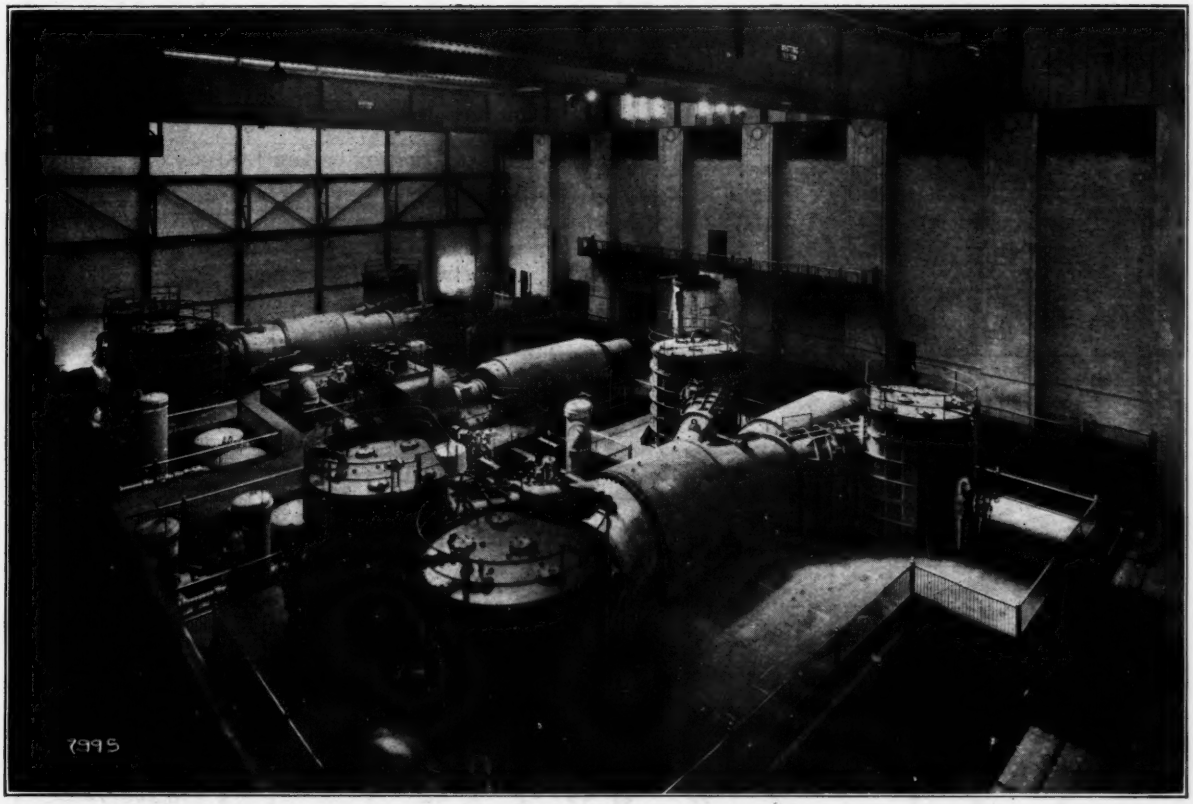


FIG. 4. GENERAL VIEW OF 208,000-KW. UNIT SHOWS 76,000-KW. HIGH PRESSURE ELEMENT IN CENTER FLANKED BY TWO 66,000-KW. LOW PRESSURE DOUBLE-FLOW ELEMENTS, EACH WITH FOUR VERTICAL CONDENSERS

730 deg. F. and exhausts at 118 lb. abs. to two steam reheaters where the temperature is brought up to 500 deg. F. before going to the low-pressure elements. Both the high-pressure and low-pressure turbines are bled at two points and another bleeder line is taken off from the high-pressure turbine exhaust.

Four points of non-throttling admission are provided for in the high-pressure turbine in order to give a flat heat consumption curve over a wide range of load. Low-pressure turbines are of the double flow type, with the wheels so arranged that each set is served by two 22,000 sq. ft. condensers making a total of 88,000 sq. ft. of condensing surface in four units for each low-pressure turbine or a total of 176,000 sq. ft. in eight units for the complete machine.

Condensate Collected in Separate Hotwells Is Pumped Through the Low-Pressure Heaters

Condensers of the vertical single pass design made up of 7/8-in. tubes 20 ft. 2 1/8 in. long. Water enters the bottom water box, passes upward through the tubes to the upper water box then downward through passages, cast integral with the shell, to be discharged through a nozzle on the lower water box. Cooling water is furnished by four 60 in., vertical circulating pumps, located in the screen house on the lake front. Each pump is driven by a 600-hp. motor.

Condensate is collected in separate hotwells and pumped through the low-pressure heaters to the boiler feed pumps. A surge tank, located just ahead of the No. 1 extraction heater takes care of load fluctuation,

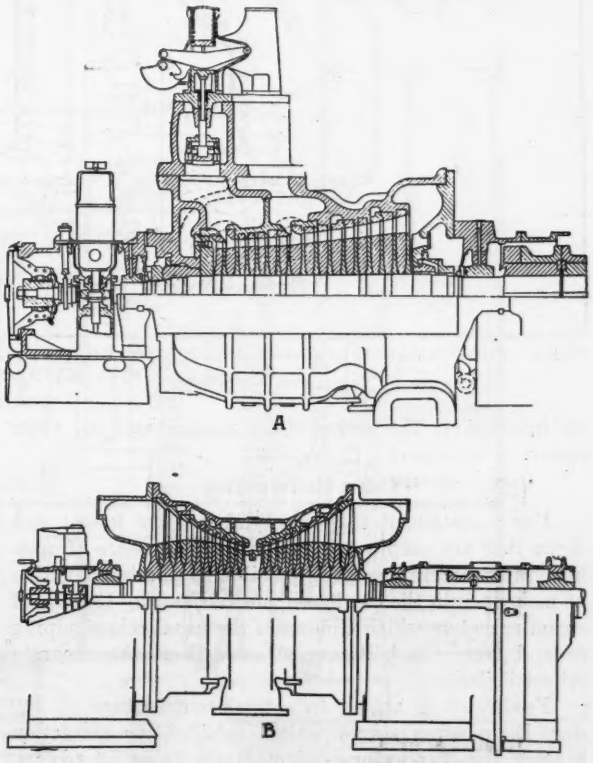


FIG. 5. CROSS-SECTIONS OF: A—THE 76,000-KW. HIGH-PRESSURE TURBINE AND B—THE 66,000-KW. LOW-PRESSURE TURBINE

flow into and out of this surge chamber being controlled from the hotwell by float valves.

For each group of four condensers there are three of these three-stage, motor-driven, double suction condensate pumps rated at 1000 g.p.m. each against a head of 225 lb., two being required at maximum load, the third serving as a spare. Air removal is accomplished by two-stage evactor air pumps. Each individual condenser has two first-stage evactors mounted upon it and lines from each set of four condensers are led to two sets of second-stage nozzles common to the four condensers. Each of these sets of second-stage equipment consists of an intercooler, the second-stage nozzles and an after cooler.

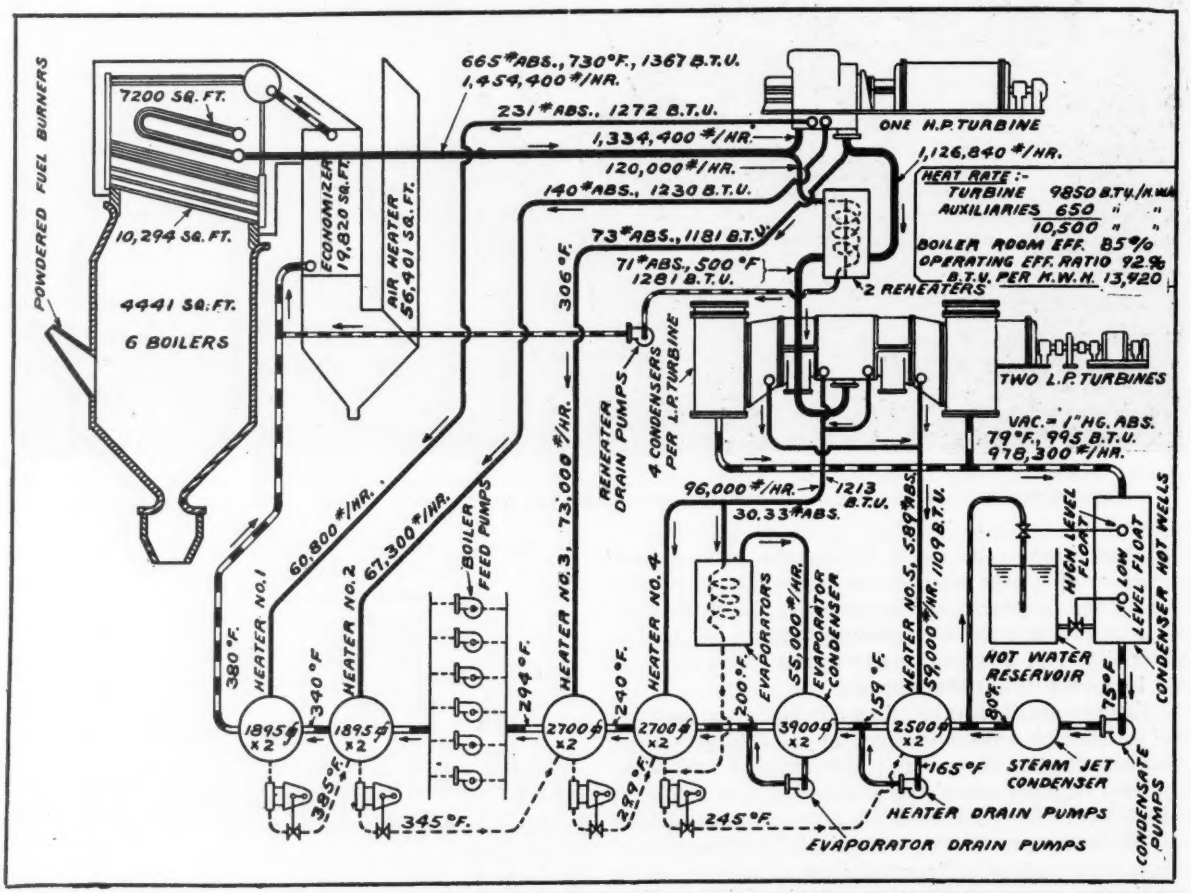


FIG. 6. PERFORMANCE DIAGRAM SHOWS HOW FEEDWATER IS HEATED TO 380 DEG. F. IN SEVEN STEPS, INCLUDING FIVE EXTRACTION HEATERS

Heat Distribution

For a station of this type and size the layout and steam flow are simple due largely to the absence of open heaters or deaerators made possible by the introduction of makeup into the condenser hotwell and by the use of steam reheaters which eliminates the usual reheat piping to and from the boiler room as well as the separate reheat boiler.

Feedwater is heated to a final temperature of 380 deg. F. in seven stages which includes five extraction heaters, the evaporator condenser and steam jet coolers. Each turbine is bled at two points and a fifth heater is supplied from the exhaust of the high-pressure cylinder. Heaters Nos. 1, 2, 3 and 4 are drained back to the low-pressure heater through traps and the combined drains pumped into the feedline ahead. Heater surfaces are 1895, 1895, 2700, 2700 and 2500 sq. ft. for Nos. 1, 2, 3, 4 and 5 respectively.

Operation of the Evaporators

Evaporators are supplied from the first bleed point on the low-pressure elements and drained to the No. 5 extraction heater. The 3900-sq. ft. evaporator condenser is placed between the No. 4 and 5 heaters. Four 800-sq. ft. submerged type evaporators operating as two single effect units with two evaporators in each unit are used. Headers are of cast steel with the shell and base of rolled steel, the heating surface being made up of 36 coils arranged in two banks of 18 each. Each pair of evaporators is designed to vaporize 40,000 lb. of water per hour using 46,500 lb. of steam at 43 lb. per sq. in. absolute and 60 deg. of superheat. One 3900 sq. ft. condenser is provided for each pair of evaporators.

Distribution of Steam to Turbine Room

At 150,000 kw. the steam flow to the turbine room is 1,454,400 lb. per hr. Of this, 120,000 lb. is used in the reheaters and as condensate pumped back to the feed line on the outlet side of the last extraction heater. Extractions at 231 and 140 lb. abs. from the high-pressure turbines are both in the superheat region. Both

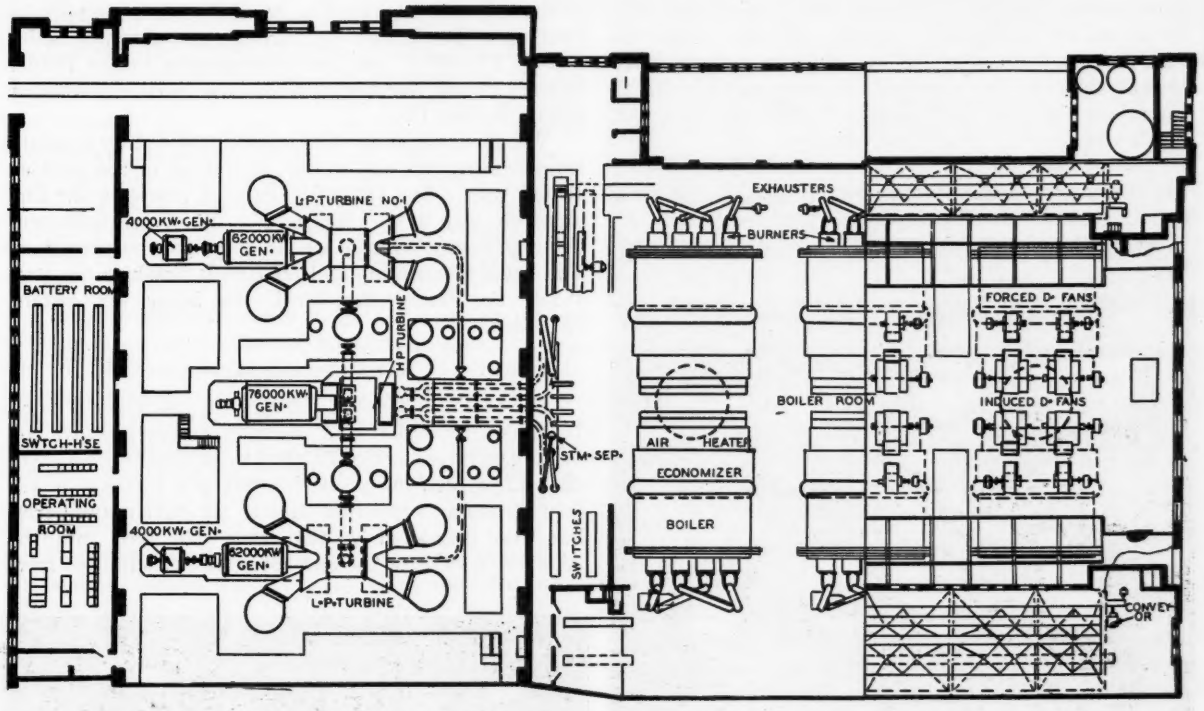


FIG. 7. GENERAL PLAN OF STATE LINE SHOWS ARRANGEMENT OF TURBINE ELEMENTS, BOILERS, PULVERIZING MILLS AND AUXILIARIES

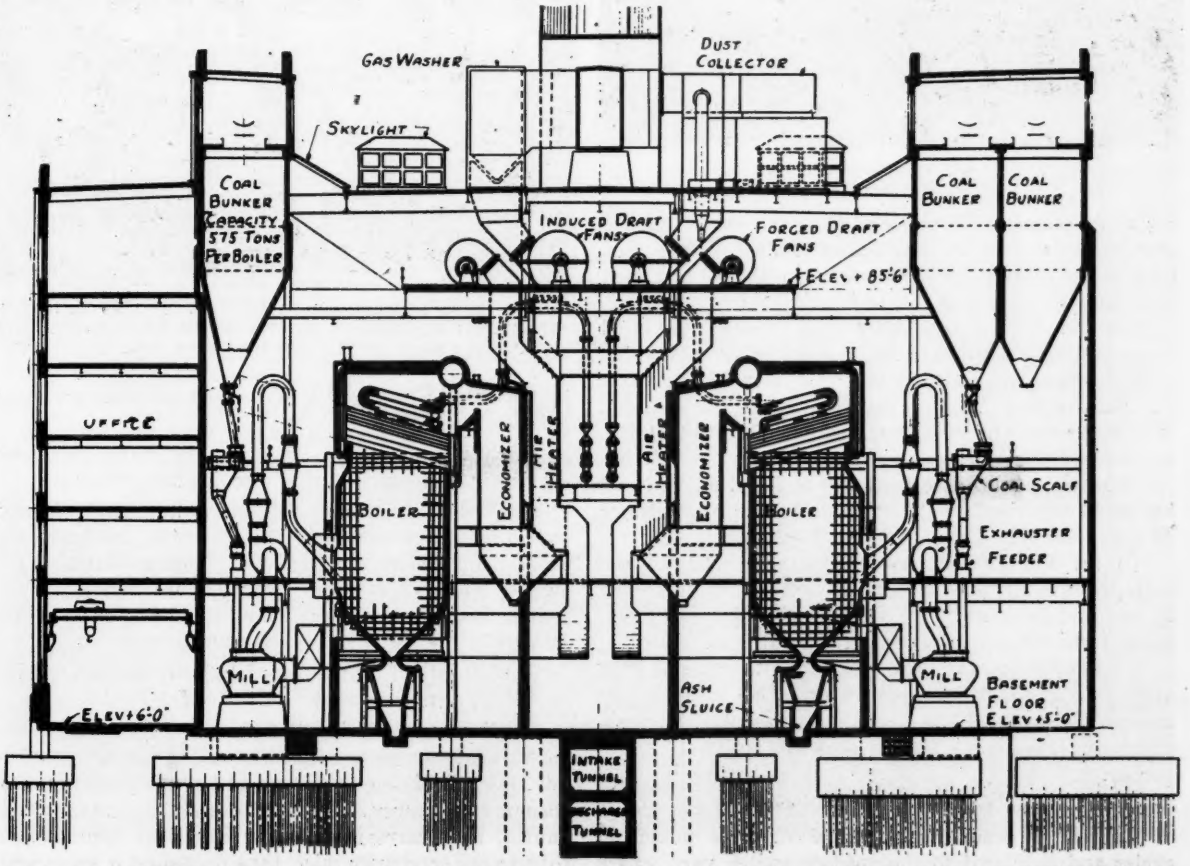


FIG. 8. ECONOMIZERS, AIR PREHEATERS AND STEAM HEADERS ARE BETWEEN THE TWO ROWS OF BOILERS, WITH FANS ABOVE THEM

high-pressure heaters are located on the discharge side of the boiler feed pump. Steam exhausted from the high-pressure element at 118 lb., almost to the saturation line, is split between the two reheaters and the No. 3 extraction heater which immediately precedes the boiler feed pumps.

Before entering the low-pressure turbines the steam temperature is raised to 500 deg. F. in the reheaters. Steam at 30.33 lb. abs. from the first bleed point of these elements is used in the No. 4 heater and evapora-

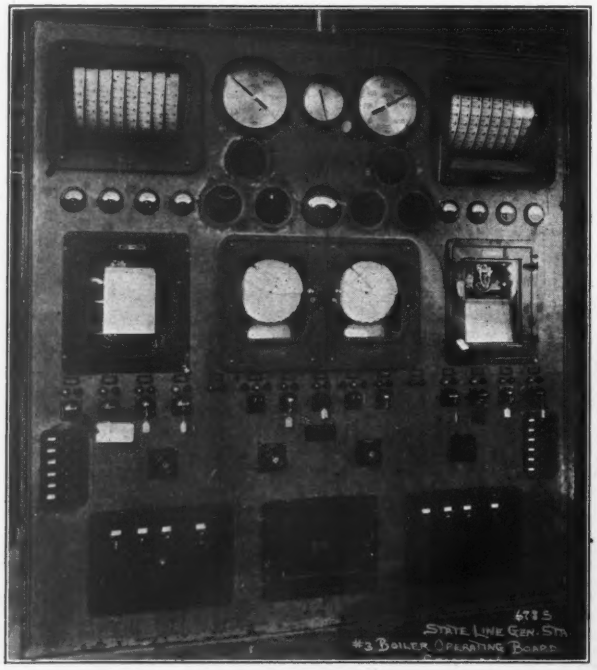


FIG. 9. BOILER CONTROL PANELS

tor while steam at 5.89 lb. abs. from the second extraction point supplies the No. 5 heater. The first extraction point from these turbines is in the superheated field and the second in the saturated field.

From a hotwell temperature of 75 deg. the final temperature of 380 deg. F. is reached in seven steps as follows: steam jet coolers 5 deg. rise from 75 to 80 deg. F.; No. 5 heater, 79 deg. rise from 80 to 159 deg. F.; evaporator condenser 41 deg. rise from 159 to 200 deg. F.; No. 4 heater 40 deg. rise from 200 to 240 deg. F.; No. 3 heater, 54 deg. rise from 240 to 294 deg. F.; No. 2 heater 46 deg. rise from 294 to 340 deg. F.; No. 1 heater 40 deg. rise from 340 to 380 deg. F.

Of the 1,334,400 lb. per hr. to the throttle of the high-pressure turbines a total of 356,100 lb. or almost 27 per cent is extracted leaving 978,300 lb. per hr. exhaust from the low-pressure turbines at 1 in. abs.

At 150,000 kw. the heat rate of the turbines is 9850 and auxiliaries 650 B.t.u. per kw-hr. This with a boiler room efficiency of 85 per cent and an operating ratio of 92 per cent gives a station heat rate of 13,420 B.t.u. per hr.

Electrical Equipment

Current is generated at 22,000 v., three phase, 60 cycles and delivered to the outdoor switch yard where it is stepped up to 33,000 v. for delivery to the Northern Indiana Public Service Co., to 66,000 v. for supply to Commonwealth-Edison Co. through underground cables and to 132,000 v. for line transmission to the Public Service Co. of Northern Illinois and Northern Indiana Public Service Co.

The three outgoing voltages are provided by separate transformers, bus and switch structures in the outdoor switch yard. The 132,000-v. current passes to the line structure seen at the back of Fig. 12, the transformers being protected by choke coils and lightning arresters. The usual disconnects and oil circuit breakers are provided, the former for local, the latter for distant operation.

Rating of Generators

For the high-pressure element, the generator is rated 76,000 kw. or 89,400 kv-a., each of the low-pressure element generators being 62,000 kw. or 73,941 kv-a. On the end of each low-pressure shaft is a 4000-kw. auxiliary generator, supplying current for station auxiliaries but also connected so that they can feed into the 33,000-v. system, or the auxiliaries can be supplied from

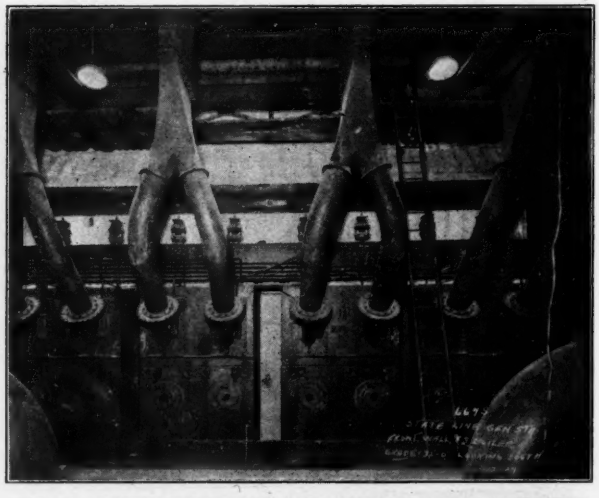


FIG. 10. EIGHT TURBULENT PULVERIZED COAL BURNERS FIRE EACH FURNACE, FOUR TO EACH MILL TO SECURE GOOD FLAME DISTRIBUTION ACROSS THE FURNACE

that system in emergency, taking current from the main generators.

High voltage lines, except the 132,000-v. lines are carried in underground ducts or in cable trenches.

Control of generators, of distribution and of yard switching is centered in the switch house, the operating room being shown in Fig. 11. Storage batteries for signals and switch-motor operation are housed in the switch house and charged by a motor-generator set located in the basement of the turbine room.

Buildings and foundations for equipment are carried on driven piles surmounted by concrete.

Cooling water is handled by vertical, motor-driven centrifugal pumps located in a crib house at the fore bay, the inlet being protected by traveling screens. To insure full supply of water in the condenser intake tunnel, it is carried above the discharge tunnel, then dips to the condenser inlet, thus providing a water seal. The forebay is surrounded by a rubble dike and dis-

charge of cooling water is outside the forebay, thus avoiding any short circuiting of the cooling water.

Probably less conduit is used in this plant than in any similar station ever built. The unsightly appearance of hundreds of conduit pipes suspended on angle iron racks of many layers from the basement ceiling of the station has been practically eliminated. To accomplish this, the cable was manufactured with a covering of flexible spiral armor and installed in groups throughout the station in large spiral steel pipes or simply laid in steel trays, the majority of which are entirely concealed.

The new station has not only the advantage of extremely large and economical generating units but it is placed reasonably near the center of the immediate territory served by the companies purchasing the station's output at the station company's property line. It has excellent rail transportation (and potential water transportation) for the delivery of cheap coal from comparatively nearby mines and has an unlimited supply of condensing water of good quality.

The present initial generating unit of the State Line Generating Station is itself larger than any other generating station in the Chicago District except Fisk Street and Crawford Avenue stations in Chicago. It is, of course, a complete power house in itself. The second section, when added, will be another complete power house; it may be different or larger than the first, exhibiting still further improvement in design to secure efficiency and economy.

Compared with another important station in the Chicago district, it is to be noted: steam pressure at State Line is 75 to 100 lb. higher; steam temperature

FIG. 11. VIEW OF THE SWITCHROOM

is about 25 deg. F. higher; steam extraction feed cycle goes much farther than before; feedwater is heated to 380 deg. F.; the air going into the furnaces is preheated to a temperature of about 425 deg. F.

As important as any of these features is the long range of high operating efficiency of the turbines of the generating group-unit, also the high boiler-plant efficiency due to the use of pulverized coal.

Concentration of electric generation on a large scale in this station and delivery to the purchasing companies at the station company's property line from which point it is carried by them over a large area, make possible more efficient service and are an added assurance to customers of an adequate and reliable supply of electrical energy at all times.

Plans and supervision of the station have been in the hands of Sargent & Lundy, Inc., of Chicago, architectural design in those of Graham, Anderson, Probst & White.

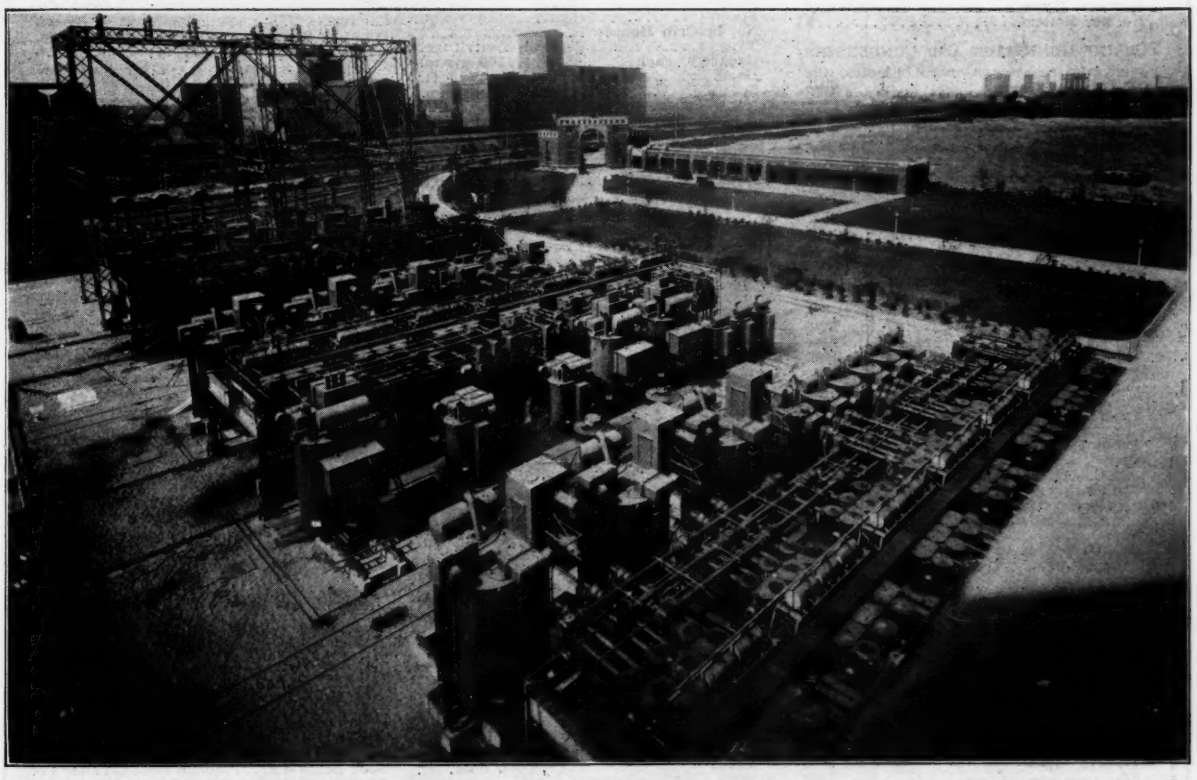


FIG. 12. OUTDOOR SWITCHYARD; CENTER SECTION STEPS VOLTAGE FROM 22,000 V., AS GENERATED, TO 33,000 V., RIGHT HAND SECTION TO 66,000 V. AND SECTION IN BACKGROUND TO 132,000 V.

Principal Equipment at State Line Station, Unit No. 1

General

Location ..... Hammond, Ind.
Water Source ..... Lake Michigan
Service ..... Power and Light
Capacity, present ..... 208,000 kw.
ultimate ..... 1,000,000 kw.
Area property ..... 90.1 acres
Owners ..... State Line Generating Co.
Consulting Engineers ..... Sargent & Lundy, Inc.
Present Building .... Vol. Cu. Ft. per kw.
Boiler Room 18.6
Turbine Room 13.9
Switch House 1.5
Crib House 1.4
Office 3.3
Total 38.7

Boilers and Auxiliaries

Standard Boilers .. Babcock & Wilcox Co.
No. 6
Water Heating Surface .... 10,294 sq. ft.
Superheater Surface ..... 7200 sq. ft.
Steam Press. Supht. Outlet .... 650 lb./g.
Steam Temp. Supht. Outlet .. 750 deg. F.
Steam Cap. Max ..... 450,000 lb./hr.
Furnace Volume ..... 22,500 cu. ft.
Furnace Side Wall Surf .... 4441 sq. ft.
Resuperheaters ... Babcock & Wilcox Co.
No. 2
Type ..... Live Steam
Cap., lb. per hr 875,000
Live steam pressure ... 600 lb. per sq. in.
Live steam temp ..... 725 deg. F.
H. P. turbine exh. press ..... 118 lb. at full load
Reheated steam to l.p. cyl., pres. 115 lb.
Reheated steam to l.p. cyl., temp. ..... 500 deg. F.
Economizers ..... Babcock & Wilcox Co.
Type ..... Steel, contra flow
Surface ..... 19,820 sq. ft.
Air Heaters ..... Babcock & Wilcox Co.
Type ..... Tubular
Surface ..... 56,401 sq. ft.
Furnace ..... Bailey Wall Refractory and Metal
Pulverized Fuel Equipment ..... Fuller-Lehigh Co.
No. Mills 12
Type ..... No. 70 Lehigh, air separation with exhauster fans
Mills per Boiler 2
Size of Mill ..... 70 in.
Capacity of Mill ..... 15-20 tons/hr.
Burners, Type ..... Calumet
No. per Boiler 8

Turbine-Generator and Condensers

Turbine-Generator .. General Electric Co.
No. Units ..... One
No. Cylinders ..... Three
Type Cyl. ..... 1 h.p. 2 l.p.
Cap. Hp. ..... 76,000 kw.
Cap. Each L. P. Main ..... 62,000 kw.
Cap. Each Aux. Gen ..... 4,000 kw.
Total Cap. Unit ..... 208,000 kw.
Steam Press. at Throttle ..... 600 lb./g.
Steam Temp. at Throttle .... 730 deg. F.
Pt. of Reheat ..... Between h.p. and l.p.
Steam Press. at Reheat ..... 115 lb. abs.—Full load
Steam Temp. to l.p. ..... 500 deg. F.
Generator Voltage ..... 22,000 v.
Speed ..... 1800 r.p.m.
Feedwater Heaters .. Griscom-Russell Co.
No. Hp. ..... Two
No. Lp. ..... Three
Type ..... Vertical, floating head
Condensing Equipt. ..... Allis-Chalmers Mfg. Co.
No. Condensers 8
Type ..... Vertical, single pass
Surface, each ..... 22,000 sq. ft.
Tubes by .... British-American Tube Co.
Type ..... ⅞ in. O.D.—18 B.W.G.—20 ft. 2⅛ in L.
Condensing Cap. ..... 200,00 lb./hr.
Circulating Water Pumps ..... Allis-Chalmers Mfg. Co.
No. ..... Four
Size ..... 60 in. by 60 in.
Type ..... Single stage, vertical
Cap., each ..... 95,000 g.p.m.
Head ..... 15 ft.
Speed ..... 190 r.p.m.
Condensate Pumps ..... Allis-Chalmers Mfg. Co.
No. ..... Six
Size ..... 10 in. by 5 in.
Type ..... 3-stage, centrifugal
Capacity ..... 1000 g.p.m.
Head ..... 580 ft.
Speed ..... 1750 r.p.m.
Air Ejector Pumps ..... Croll-Reynolds Engineering Co.
No. ..... One
No. First-Stage Ejectors 16
Comb'd Inter and After Coolers 4
Second-Stage Ejectors 12
Capacity ..... 42 c.f.m. at 1 in. abs.
Steam Consumption ..... 1950 lb./hr.

Fans and Stacks

Forced Draft Fans .. B. F. Sturtevant Co.
No. 12
Type ..... Turbovane, vane control
Cap., each ..... 60,000 c.f.m.
Press. ..... 7.5 in.
Speed ..... 1160-870 r.p.m.
Drive ..... Motor
Induced Draft Fans .. B. F. Sturtevant Co.
No. 12
Type ..... Double inlet, Turbovane
Capacity ..... 110,000 c.f.m.
Gas Temp. Max ..... 400 deg. F.
Press. ..... 10.5 in.
Speed ..... 865-690 r.p.m.
Drive ..... Motor
Stacks ..... Henry Pratt Co.
No. 2
Type ..... self-sup. steel
Diameter ..... 22 ft. 6 in. at base
Height ..... 250 ft. above b.r. floor

Boiler Feed and Other Pumps

Boiler Feed Pumps ..... Worthington Pump & Machinery Corp.
No. Motor Driven 6
Size ..... 5 in.
Type ..... 8-stage, volute
Cap., each ..... 900 g.p.m.
Head ..... 2050 ft.
Speed ..... 1760 r.p.m.
Turbine Driven ..... DeLaval Steam Turbine Co.
No. 4
Size ..... 6 in.
Type ..... 6-stage, centrifugal
Capacity, each ..... 900 g.p.m.
Head ..... 2050 ft.
Speed ..... 1760 r.p.m.
Heater Drain Pump ... Ingersoll-Rand Co.
No. 4
Type ..... 3-stage Cameron
Capacity ..... 500 g.p.m.
Head ..... 250 lb./sq. in.
Speed ..... 1800 r.p.m.
Bilge Pumps ..... Yeomans Bros. Co.
No. Total 4
No. in Turbine Room 2
Type ..... Vertical, centrifugal
Capacity, each ..... 250 g.p.m.
Head ..... 20 ft.
Speed ..... 1150 r.p.m.
No. in Crib House 2
Type ..... Vertical, centrifugal
Capacity, each ..... 250 g.p.m.
Head ..... 40 ft.
Speed ..... 1150 r.p.m.
Service Pumps ..... Worthington Pump & Machinery Corp.
No. 5
Type ..... Volute, centrifugal
Capacity ..... 1200 g.p.m.
Head ..... 183 ft.
Drive 4-motor, 1-turbine
Fire Pumps ..... Worthington Pump & Machinery Corp.
No. 1
Type ..... 4-stage, Volute
Capacity ..... 1000 g.p.m.
Head ..... 505 ft.
Boiler Wash Pump ..... —Worthington Pump & Machinery Corp.
No. 1
Type ..... 3-stage, turbine
Capacity ..... 600 g.p.m.
Ash Sluicing Pump ..... Worthington Pump & Machinery Corp.
No. 2
Type ..... Volute, centrifugal
Capacity ..... 1200 g.p.m.
Reheater Drain Pumps ..... Ingersoll-Rand Co.
No. 2
Type ..... 3-stage, Cameron
Capacity ..... 125 g.p.m.
Head ..... 300 lb.
Speed ..... 3500 r.p.m.
Evaporator Condenser Drain Pumps .. Worthington Pump & Machinery Corp.
No. 2
Type ..... Volute, 4-stage
Capacity ..... 80 g.p.m.
Speed ..... 1750 r.p.m.
Drive ..... Squirrel cage motor

Evaporators and Filters

Evaporating System . Foster Wheeler Corp.
No. Evaporators 2
Evaporator Condenser 1
Type, Con. ..... Vertical, contra-flow
Capacity ..... 40,000 lb. dis. water/hr.
Type, Evap. Con. ..... Vert. float. hd.
Water Filter System ..... Paige & Jones Chemical Co. System ... 8 units, gravel and filter tank
Capacity each ..... 150 g.p.m.

Coal and Ash Handling

Coal Handling Equipt . Koppers Const. Co.
Capacity ..... 500 ton/hr.
Breaker, No. and Cap .... 2—250 ton/hr.
Car Dumper ..... 60 ft. rotary
Cap., Max ..... 120 ton
Size Conveyor Belt ..... 42 in.
Speed of Belt ..... 360 f.p.m.
Coal Storage Equipt . R. H. Beaumont Co.
Type ..... Drag Line Scraper
Capacity ..... 300 ton/hr.
Speed ..... 200 f.p.m.
Coal Scales ..... Richardson Scale Co.
No. 12
Type ..... Automatic, apron feed
Cap., each ..... 15-20 ton/hr.
Ash Handling Equipt ..... Allen-Sherman-Hoff Co.
Installed with ..... 6 boilers
System ..... Ash hoppers gates and hydrojet handling

Electrical Equipment

Outdoor and Indoor Switch Equipment ..... General Electric Co.
Transformers ..... General Electric Co.
Electric Equipment Erection ..... Pierce Electric Co.
Miscellaneous Motors ..... Allis-Chalmers Mfg. Co.
Automatic Telephone ..... Automatic Telephone Co.

Other Mechanical Equipment

Traveling Screens ..... Link-Belt Co.
No. 5
Width ..... 92 in.
Center Distance ..... 35 ft. 6 in.
Speed ..... 10 f.p.m.
Steam Receiver ..... M. W. Kellogg Co.
Type ..... Forge & Hammer Weld
Circulating Water Piping ..... M. W. Kellogg Co.
Cast Iron Fittings ..... Crane Co.
Cir. Pump Disch. Fittings ..... Crane Co.
Motor Operated Gate Valves ... Crane Co.
Superstructure ..... Herlihy Bros. Co.
Mach. Foundations ..... Herlihy Bros. Co.
City Water Line ..... J. J. Nejdl
Crib House Substructure ..... United Gas Improvement Construction Co.
Sewerage System ..... Nash Bros.
Repairing Breakwater ..... Fitzsimmons-Connell Dredge & Dock Co.
Cafeteria ..... Emerson B. Brown
Turbine Room Crane ..... Whiting Corp.
No. 2
Type ..... Double trolley
Cap., Main Hoist ..... 75 ton
Cap., Aux. Hoist ..... 15 ton
Span ..... 130 ft.
Lift ..... 67 ft. 3 in.
Air Compressors .. Sullivan Machinery Co.
No. 2
Type ..... 2-stage, angle compound
Capacity ..... 610 c.f.m.
Pressure ..... 100 lb./sq. in.
Automatic Combustion Control ..... Leeds & Northrup Co. For Six Boilers and Auxiliaries.
Boiler Settings ..... National Power Construction Co. For Six Boilers and Economizers.
Economizer Arches . Bigelow-Liptak Corp.
Type ..... Suspension, refractory
Flues, Uptakes, Air Ducts ..... Henry Pratt Co.
Miscellaneous Steel and Iron Work ..... Vierling Steel Works
Coal Transfer Car ..... McMyler Interstate Co.
Capacity ..... 75 ton
Dust Collectors
Vorticose Dust Collectors.
No. 2
Nor. Gas Cap .. 110,000 c.f.m. at 350 deg.
Max. Gas Capacity ..... 220,000 c.f.m.
Press. Drop at Max. Rating ..... 1.75 in.
Sirrocco Dust Collectors.
No. 4
Nor. Gas Cap .. 160,000 c.f.m. at 350 deg.
Max. Gas Capacity ..... 220,000 c.f.m.
Press. Drop at Maximum Rating . 2.78 in.
Green Dust Recovering Devices
No. 2
Nor. Gas Capacity ..... 160,000 c.f.m.
Max. Gas Capacity ..... 220,000 c.f.m.
Press. Drop at Maximum Rating . .07 in.
Piping System ..... Wm. A. Pope
Complete system for one 208,000-kw. turbine, six boilers, auxiliaries and appurtenances.
Piping, Duct, Boiler Insulation ..... Johns-Manville Corp.
Soot Blowers .... Vulcan Soot Cleaner Co.
Vacuum Cleaning System ..... Atwood-Stewart Vacuum Machine Co.

Application of the RECTOX RECTIFIER *to Industrial Control*

AMONG THE MANY startling developments in the electrical field during recent years, one of the most interesting is that of the so-called "dry" type of rectifiers for producing direct current from alternating current. The production of direct current from alternating current without the use of rotating machinery

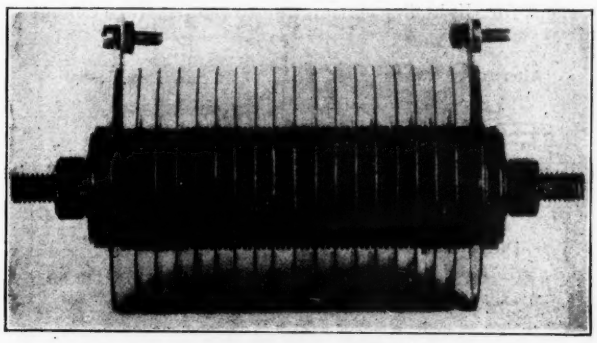


FIG. 1. A SINGLE COPPER OXIDE RECTIFIER UNIT

has long been a problem of interest to the electrical engineer and while a number of rectifiers have been developed, until quite recently, few of these with the one exception, perhaps, of the mercury arc rectifier, were marked by any high degree of success.

Before the development of the dry rectifier, the most successful types were the dry or wet electrolytic, the vibrating mechanical rectifier, the mercury arc and the hot cathode types. Of these, the most reliable and most generally used were the hot cathode, gas-filled tubes exemplified by the Rectigon and the Tungar rectifiers used for charging radio and automobile batteries. While this type of rectifier is excellent for charging batteries, it has certain definite limitations both as to voltage and to current output which has made it inapplicable to industrial uses.

For industrial uses, a rectifier cannot succeed if it has the limitations of any of the earlier types—whether it be a fragile tube, requiring replacement or an electrolytic device, requiring either replacement or maintenance.

Among the new type rectifiers, one which seems to have none of the disadvantages which have limited the application of other rectifiers, is the Rectox rectifier. This rectifier and its application to industrial control is described in the September number of the Electric Journal, by D. Santini and I. R. Smith, both of the Westinghouse Electric & Manufacturing Co.

The Rectox, the authors state, is reliable, having a life of indefinite length, so far as is now known, and is rugged as well. Being so, it can withstand handling and shipment without danger of being damaged. It is dry, being completely metallic, and having no moving parts, it operates without noise. It produces almost a perfect rectified wave form with small reverse current. It operates electronically, not electrolytically, therefore requiring no preliminary forming. Full wave connections are made with great facility so that, if desired, the Rectox can operate directly from a line of any number

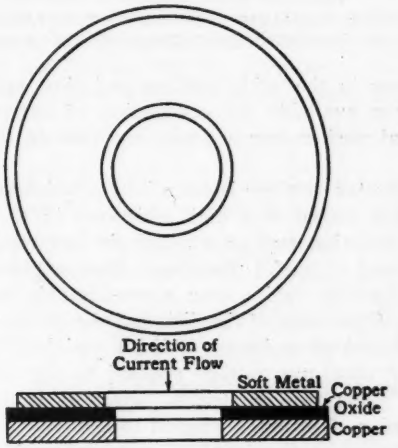


FIG. 2. TOP AND SECTIONAL VIEWS SHOWING THE RECTIFIER DISK ARRANGEMENT

of phases without intervening transformers. Its thermal capacity is high so that, for short-time operation, the Rectox can be greatly overloaded without damage. The units can be connected in series or parallel without difficulty and require no filament excitation.

This rectifier was discovered several years ago by L. O. Grondahl. The first units made in 1924 were used to operate relays in train control equipment. Since then, Rectox units have been built for use in almost every conceivable application where direct current is needed and only alternating current is available.

During this period, many industrial uses for the copper oxide rectifier have been and are still being developed. One interesting application is in the use of the new rectifier in elevator control.

In the manufacture of the copper oxide rectifier, the cuprous oxide is formed directly on one side of the mother copper. This results in an integral metal oxide combination having pronounced asymmetric conductivity since current flows readily in the direction of oxide to copper but with great difficulty in the reverse direction.

Constructional Features

Starting with the copper-cuprous oxide combination, which in the Rectox is made in the form of a washer as shown in Fig. 2, the rectifying element is built up. A soft-metal washer is placed between the copper cuprous oxide washers so that it is in contact with the cuprous oxide of one disk and the copper of the next. The purpose of this soft metal washer is solely to improve contact, the soft metal accommodating itself to

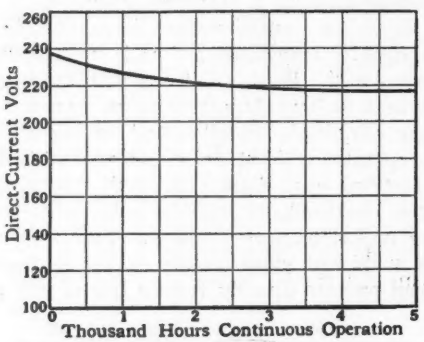


FIG. 3. THE VARIATION OF OUTPUT VOLTAGE WITH TIME OF A THREE-PHASE, 230-V., 60-CYCLE RECTOX

unevenness in the oxide surface and thus making the whole area available for conduction of current. The soft metal washer does not take any part in the rectification.

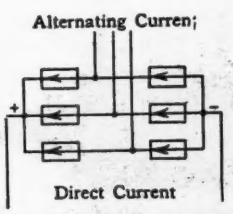
The Rectox rectifier is essentially a resistance device, the washer acting as a high resistance in the back or reverse direction and as a relatively low resistance in the forward or useful direction. The resistance in the useful direction varies over a considerable range, depending on the area of the disk and the current density. The back or high resistance is also a variable, depending upon the area and voltage applied to the disk. The ratio of these two resistances, however, is very high, of the order of several thousand to one.

In the application of the rectifier, assuming the use of proper current densities and voltages, attention is paid to the matter of temperatures. This is necessary because both the useful and the high resistance characteristics vary with the temperature, decreasing with a rise in temperature. Obviously, decreasing forward resistance is an advantage, since it improves regulation and efficiency, but decreasing back resistance is a move in the wrong direction. The result is increase in back current with increased heating in the rectifier, a process which would be cumulative if unchecked and would result in instability and eventual failure. Rectifier designs, then, must include adequate radiating surfaces. Apparatus designs must provide for adequate radiation and ambient temperatures must be considered in designing an installation.

It is also necessary in the design of a Rectox rectifier, to provide for the change in rectifier resistance which occurs in use. The rectifier undergoes a certain aging during which forward resistance tends to increase somewhat and back resistance to decrease for a time after the rectifier has been put in service. Some change takes place even in the absence of actual operation, that is, on the shelf, but this has been minimized by manufacturing refinements to such a degree that it is relatively unimportant.

Obviously, the effect of this alteration in characteristic, is to lower the rectification ratio and to introduce more resistance in the circuit, thus decreasing the output. Immediately it becomes necessary to know how the change occurs, how great it may be and whether the unit eventually stabilizes. These questions are answered from a very considerable laboratory experience involving many hundreds of units of all types; some extending over more than 5 yr. time as well as from actual service experience with hundreds of thousands of rectifiers built during the period.

Experience has shown that the greater part of this change occurs soon after the rectifier has been put in service, that is, within the first four or five months. Subsequent changes are very gradual, until, at about the end of the first year, the unit becomes constant except for slight fluctuation due to temperature changes.



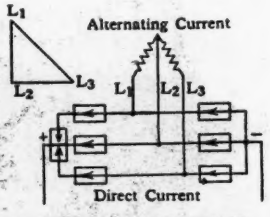


FIG. 4. THREE-PHASE RECTIFIER CONNECTIONS
FIG. 5. TWO-PHASE, THREE-WIRE RECTIFIER CONNECTIONS

A typical curve showing variations in output voltage with time is given in Fig. 3. This gives a clear picture of the nature of the change. With this rectifier, a 9 per cent drop in output occurred in about 5300 hr. of continuous operation with no indications of any limitations to the life of the rectifier. In general, it is simple to compensate for this change in characteristic by providing for frequent extra capacity to permit all of the drop in output to take place above the rating of the output so that after it has aged the rectifier will still deliver its rated voltage and current.

Another method of taking care of this change is to increase the voltage applied to the rectifier when necessary by varying a ballast resistor or reactor, or else by changing taps on a supply transformer. Choice of method depends, of course, upon the application and the conditions to be met.

Application of the Rectox rectifier to elevator control is especially interesting. The design of alternating current elevator control, with which should be included alternating current brakes, has always been a more or less troublesome matter. Not only is alternating current control more difficult to design than direct current control, but it is generally more costly to build. The problem of getting rid of hum is always hard to solve, as well as the clatter with which the alternating current magnet operates. By providing a simple source of direct current, the Rectox rectifier lends itself to the elimination of all such troublesome features in an economical

manner and without any complication in control design. Especially is this of advantage in the case of magnetic elevator brakes. Here, by using the Rectox, the direct current brake can be applied with its inherent characteristic of quietness, smoothness in operation and wide operation range which are so essential in elevator application of the passenger type particularly.

Rectox design for control application has been standardized to the point where a single unit, shown in Fig. 1, in various combinations, meets practically all the requirements. The units are ordinarily used in full wave connection. The facility with which full wave connection can be obtained is an important advantage of the Rectox. The connection used is the well-known bridge type of connection, which can be built for any number of phases. Such a rectifier would consist of one leg for each phase with the negative direct current terminal at one end of each leg and the positive at the other end and alternating current lines connecting at the mid-point. The washers, of course, would be stacked

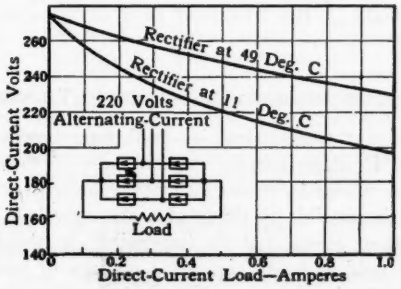


FIG. 6. RECTIFIER SUPPLIED FROM A THREE-PHASE SYSTEM

to permit the current to flow from negative to positive through each leg.

For 230-v., 3-phase supply, then, we would require three legs as shown in Fig. 4. For convenience each of these legs is composed of two units such as shown in Fig. 1, making a total of six units for a complete 3-phase full wave rectifier. Such a rectifier is suitable for mounting on the back of a 24-in. control panel. It has a continuous output capacity of 100 w. The output obtained might be called 6-phase direct current and has very good characteristics.

For 230-v., 2-phase, 4-wire service, 4 legs or a total of 8 units will be required. This connection is simply two single-phase rectifiers with the direct current points joined.

A 230-v., 2-phase, 3-wire connection is a special case and requires an extra rectifying unit on account of the higher voltage between the two outside wires. This connection is shown in Fig. 5 and illustrates the adaptability of the Rectox to special conditions.

The voltage output depends upon three factors—first, regulation of the rectifier, second, line voltage variation, third, changes in the rectifier resistance. Since the Rectox is essentially a resistance device, it is to be expected that as load increases the output voltage will drop. This is illustrated by Figs. 6, 7 and 8. Figure 6 shows that for 220 v. alternating current a normal voltage of 275 v. direct current is obtained. At 0.5 amp. the rated output current, the voltage is 247. This same figure also shows that with decreasing temperature the Rectox resistance increases. The direct current voltage of the same unit at 11 deg. C. and 0.5 amp. will be approximately 220. The rectifier load may vary from 0 to 0.5 amp. and output voltage will be affected as already shown. Line voltage may vary from 250 v. down to 210. Combining the lowest voltage, namely 210, and the full load current, 0.5 amp., this rectifier will deliver about 220 v. direct current.

Curves shown in Figs. 7 and 8 make it evident that 3-phase is preferable in order that a high direct

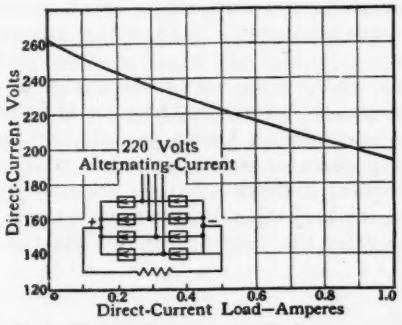


FIG. 7. RECTIFIER SUPPLIED FROM A TWO-PHASE, FOUR-WIRE SYSTEM

current voltage may be obtained, which will permit the use of standard contactor coils.

Effect of temperature is shown in Fig. 6. The low voltage shown at the lower temperature would seem to be a disadvantage were it not for the fact that at low temperature the contactor coil resistance is also low, requiring less voltage for its operation. As the coil heats, the rectifier temperature will also increase, so

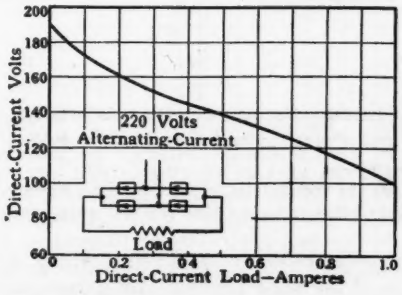


FIG. 8. RECTIFIER SUPPLIED FROM A SINGLE-PHASE SYSTEM

that its voltage will automatically rise and at the rate required.

For a given load, the rising temperature of the rectifier will, of course, depend upon the design of the unit, that is, upon the ratio of heat radiating surface to the amount of heat to be dissipated. Each design of unit will have a maximum safe operating temperature which, of course, must take account of ambient temperature as well as rise. As pointed out, exceeding the maximum safe temperature is unwise since the circulating current will tend to increase. Continued overheating may then result in failure. Rectifiers must be designed for a definite maximum ambient temperature as well as for a definite rise in full load. Adjusting the rectifier design to different ambience is only a matter of providing sufficient radiation, units having been made for ambience as high as 80 deg. C.

Electricity---What It Is and How It Acts*

PART XXXI. PRINCIPLES INVOLVED IN THE PRODUCTION OF ELECTRO-MAGNETIC WAVES. SUITABLE CIRCUITS FOR EFFECTIVE RADIATION. BY A. W. KRAMER

RADIATION OF electromagnetic energy is a complex phenomenon and, at best, is only imperfectly understood. The methods employed to explain it are necessarily makeshifts and must not be taken too seriously; yet they serve a purpose. If, by means of them, we can form a logical mental picture of what happens and if this picture at the same time substantiates to a degree the mathematical deductions, their use is justified. In that form of radiation known as light, we have seen, there is a question as to whether it is a wave motion in an hypothetical medium called the ether or whether it consists of the projection of innumerable small particles of energy from the light source. While the form of

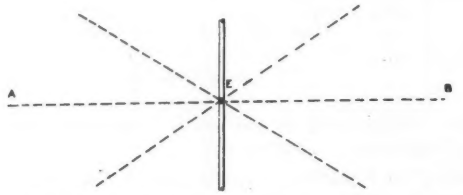


FIG. 1A. LINES OF ELECTROSTATIC FORCE TERMINATING ON AN ELECTRON IN A VERTICAL CONDUCTOR

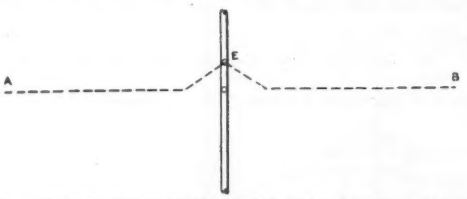


FIG. 1B. HERE THE ELECTRON HAS MOVED UPWARD FROM THE POSITION SHOWN AT A AND HAS PRODUCED A KINK IN THE LINES OF FORCE. IN THIS DIAGRAM, ONLY THE LINES AE AND EB ARE SHOWN BUT THE SAME, OF COURSE, IS TRUE FOR ALL OTHER LINES OF FORCE CONSTITUTING THE FIELD ABOUT THE ELECTRON

electromagnetic radiation characterized by radio phenomena is of the same fundamental nature as light, the particle theory in this instance is not so applicable and, to explain it, we still must rely upon the existence of some medium in the space surrounding the source of radiation. At the present time, the ether which was so generally accepted twenty years ago, is in bad repute and has gone into the discard, so to speak, so we must find a substitute. This has been done by imparting concrete reality to the electric and magnetic fields which surround all moving electric charges. When we assumed the existence of an ether, an electrostatic line of force between two charges could be regarded as a line of strain in the ether between them. With this conception, the field consists merely in a modification in the medium surrounding the charge and exists merely because of the presence of the ether. Without the ether in this case, one could no more think of an electric field than one could think of a whirlpool in a rapids without water.

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If, however, the field of force is given objective reality by assuming that actual lines of force extend outward radially from every electric charge, it is evident that the existence of an intangible ether is no longer essential. This seems to be the view most generally accepted today.

In his lectures on relativity delivered shortly before he died, Steinmetz stated: "The hypothesis of the ether has been disproved and abandoned. * * * The magnetic lines of force surrounding the earth can easily be conceived as lending themselves to all the requirements of wave propagation. The magnetic field offers a continuous and elastic medium and has a tendency to return to its original position. This is proved on a smaller scale in the distorted field of an electric generator."

FACTORS INVOLVED IN SCIENTIFIC THINKING

Whichever conception is employed, however, it is necessary to make certain assumptions of the presence of entities whose existence has never been proved. For if it was impossible to think of a structureless, imponderable ether, it is just as impossible to think of the magnetic field as being composed of lines of force which have an actual existence. The first question that comes to mind is, of course, what are the lines of force made of? And to that there is no answer. Maxwell, who enunciated the electromagnetic theory never committed himself to any opinion as to the exact nature of the physical change which he called the electric displacement.

While this state of affairs may seem, offhand, to be unscientific and somewhat discouraging, upon more careful consideration it is perhaps not so discouraging as at first it may seem and its scientific aspects will be found quite on a par with other scientific matters. After all it is entirely possible that many things in nature cannot be explained in language other than mathematics and if that is true, any explanation which gives consistently accurate results is a correct one; certainly it can never be disproved. There may in fact be several different ways of explaining the same phenomena and if each of these methods gives equally accurate results, none can be said to be wrong and all will be correct.

Mr. Oliver Heaviside paradoxically enough once made the remark that the more general or the more vague a physical theory was, in one sense, the more likely it was to be true, or perhaps we should say the more less likely it is to be untrue.

So, in our discussion of radiation phenomena, when we refer to lines of force or the ether, it is possible we are giving names to things which do not exist or if they do, their nature is entirely different from that which we picture in our minds, yet, if by these conceptions we are enabled to "understand" the phenomena, we may well ascribe to them a real existence.

The question whether a line of force, electrostatic or

magnetic, is to be regarded as a convenience of thought similar to a line of latitude or longitude or whether it has objective reality is too large to discuss here fully. It is a question more properly considered in the theory of relativity and Professor Eddington in his book, "The Nature of the Physical World," discusses this subject with enviable skill.

There are some good reasons, however, for considering that in a space occupied by air or gases, at least, in which electric force exists, the force may not be distributed entirely without discontinuity. Thus in considering radiation phenomena, it will be assumed that each electron has attached to it a number of lines of force, extending radially outward into space. The existence of these lines obviously make the presence of an ether superfluous; however, if the idea of an ether

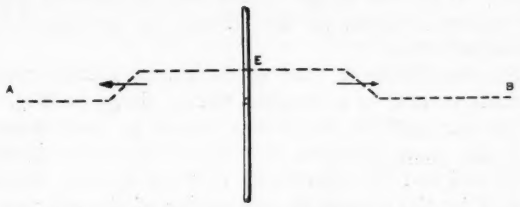


FIG. 2. IN THIS DIAGRAM, THE KINK PRODUCED BY THE MOVEMENT OF THE ELECTRON HAS TRAVELLED OUTWARD ALONG THE LINE OF FORCE WHILE THE LINES OF FORCE AT THE ELECTRON HAVE RESUMED A POSITION NORMAL TO THE ELECTRON

still appeals to us we can use Professor Morecroft's conception and picture the ether as consisting of the superimposed lines of force of all the electrons in the Universe. Upon these lines, or more correctly along them, energy can be transmitted as a wave motion.

Characteristics of Wave Motion

One of the physical characteristics of wave motion is that, by it, energy is conveyed entirely away from the wave creating body and exists for a time stored up in the surrounding medium. The effectiveness of any wave motion, however, seems to be intimately related to the periodicity or frequency of oscillation. If a fan is moved through the air slowly, all that happens is that the air in front passes around behind it and in so doing air vortices are created. It is quite different, however, if the fan is moved or vibrated rapidly so as to bring into play the inertia quality of the air or other fluid through which the fan may be moving. If, for instance, instead of moving somewhat slowly through the air, the fan or some other body such as a tuning fork is made to vibrate rapidly, the inertia and compressibility of the air come into play with the result that we have true wave motion produced; the air has not had time to get out of the way of the moving solid and thus, instead of moving around to the back of the vibrating body, it is suddenly compressed and subsequently rarefied and started into oscillations. Each portion of the air takes up, successively, the oscillatory motion or changes of pressure and energy is conveyed entirely away from the moving body and its neighborhood and continues to exist in the medium as a wave long after the vibrating body which started it has come to rest.

So much for the mechanics of wave motion. Let us now return to the electron. From our study of the action of the electron in vacuum tubes, we have seen that an electron possesses inertia. To accelerate an electron, work must be done on it; if it is retarded in its motion, it must give up part of its kinetic energy. We have seen also, or rather, we assumed also, that each electron has attached to it a number of lines of force. Now it appears that at least a part (perhaps all of it) of the inertia which the electron possesses is vested in these lines of force and that the work done in accelerating the electron is work done on the lines of force.

Production of Electric Waves

Suppose a charge with its connecting lines of force moves through space with a uniform velocity. If this charge is suddenly retarded, the ends of the lines terminating on it will be, so to speak, jerked backwards. In accordance with the properties of lines of force, this kink created at the end of the line will not be transmitted along the whole line instantaneously but will be propagated along it with a finite velocity—that of light. Each portion of the line will take up successively the motion produced at the end of the line by the sudden retardation of the electron; thus a kink or a wave is transmitted outwards away from the electron. These kinks in the lines are the seat of that part of the energy which the electron gives up when retarded. This action can, perhaps, be made clearer by an illustration.

Suppose that a single free electron is located in the center of a vertical electrical conductor as shown in Fig. 1A. This electron has lines of force terminating

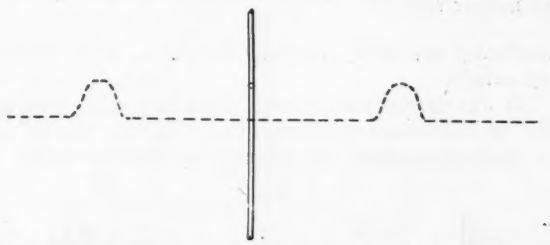


FIG. 3. SHAPE OF WAVE PRODUCED BY A SINGLE UP AND DOWN MOVEMENT OF THE ELECTRON

on it extending outward in all directions as shown but for our purpose here we will consider only those two extending horizontally to the right and left of the conductor, those labeled AE and EB. As long as the electron remains stationary, the lines of force will remain straight. Suppose, however, that the electron is suddenly accelerated upwards by the application of an electromotive force across the terminals of the conductor. It is evident that those portions of the lines of force nearest the electron will also be drawn upward, producing a kink as shown in Fig. 1B. If the electron now comes to rest at this higher position, the lines of force will once more straighten out near the electron. Since the motion of the electron is not transmitted instantly to all parts of the lines of force, it is evident that at some place along the line, its direction is still toward the original position of the electron. The kink or wave, therefore, will be somewhere between such portions of the lines and the readjusted portions closer to the electron. Thus the kink travels outwards.

If upon reaching an upper position, the electron instead of coming to rest, immediately starts downward, a wave of the shape shown in Fig. 3 will be propagated along the line. In other words, the motion

of the electron in a conductor will be simulated exactly by each portion of a line of force, successively as the energy travels outward from the conductor. If the electron, instead of merely moving up and down once, continues to oscillate, a continuous wave will be sent out along the lines of force as shown in Fig. 4. This in the most simple manner illustrates the fundamental principles involved in the transmission of energy by electromagnetic waves. As will be shown later, the action is more complicated but the principle remains essentially the same.

Further Considerations Regarding the Production of Oscillatory Currents

Before proceeding with a more detailed discussion of this subject, let us investigate further the method of

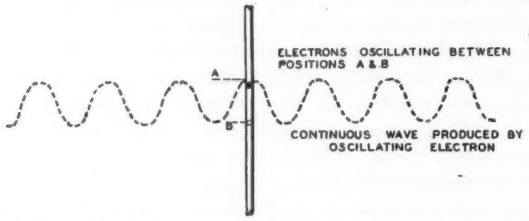


FIG. 4. DIAGRAM SHOWING THE PRODUCTION OF CONTINUOUS WAVES

In this case, the electron is oscillating at a uniform frequency between the positions A and B along the rod. This movement results in the production of continuous waves along the lines of force.

producing oscillatory currents described in the preceding article.

It was shown that a circuit consisting of a condenser and an inductance coil could, under suitable conditions, be made to produce an alternating current which in

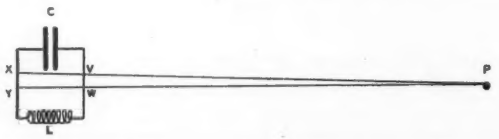


FIG. 5. NON-RADIATING TYPE OF OSCILLATORY CIRCUIT

The magnetic field produced at point P by the current in any element X-Y of the circuit is neutralized by the field due to the current in any other element V-W. The current in a section XY at any instant is always in the opposite direction to the current in a section V-W on the opposite side of the circuit.

turn produced in the space surrounding the circuit alternating magnetic and electric fields. As was shown in an earlier article,[1] these fields are capable of inducing alternating currents in other nearby circuits even though such circuits have no electrical connection with the circuit generating the oscillations. This is the principle of electromagnetic induction utilized in all generators, transformers, motors, etc.

While the transfer of energy from one circuit to another in this manner is true "wireless" transmission of energy, a circuit of the type described consisting of a closed circuit containing inductance and capacity is incapable of transmitting energy over long distances because of the neutralizing effect of the current in opposite sides of the circuit. This can be explained by the following example.

[1]Part XIV.

A point P is located at a considerable distance, 1000 ft. or more, say, from a closed oscillatory circuit as shown in Fig. 5. Since the current in this circuit flows alternately in a clockwise and counter clockwise direction, it is evident that in a section, X-Y the current will flow alternately upward and downward. This current (in the section X-Y) will of course tend to produce an alternating field at the point P. A current also flows in another section of the circuit V-W, however, and since this current is always equal and opposite in direction to that flowing in the section X-Y, the field created at P by this current always exactly neutralizes the field produced by the current in X-Y. As a result of this neutralizing action of one half of a closed oscillatory circuit upon the other half, there will be no appreciable radiation from the circuit, except when the point P is so close to the circuit that its distance from the various sections of the circuit can no longer be considered equal.

Suppose, however, that an oscillatory current could be made to flow in a straight rod as shown in Fig. 6. If this were possible, the current would at every instant be in the same direction throughout the entire length of the rod and the alternating field set up at a distant point P by the current in one section of the rod would

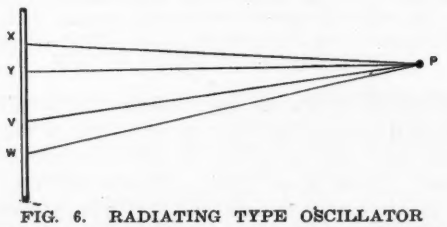


FIG. 6. RADIATING TYPE OSCILLATOR

In this "open" type oscillator, the field produced at P by the current in any element X-Y is augmented by the field produced by the current in any other element V-W. Such an oscillator, therefore, is an effective radiator.

not be in opposition to the field set up by the current in another section of the rod. Such an "open" oscillator, therefore, would radiate energy much more effectively than the closed circuit previously considered and if we are to make use of the radiating properties of an oscillatory current, this is the type of circuit that must be employed.

The method of producing oscillations in an open circuit is a fundamental factor in radio transmission and the way it is accomplished will be described in detail in the next article of this series.

The point which we have endeavored to make clear in this article, is that an oscillating electron in a suitably designed circuit will produce waves which move outward along the lines of force. While these waves have been described and depicted in a very simple manner, for purposes of illustration, in reality they are complex, having both an electrostatic and electromagnetic component. These points also will be considered in detail in later articles.

Production of electric power by public-utility power plants in the United States for August, 1929, according to the Geological Survey, Department of the Interior, reached a total of 8,259,426,000 kw-hr., an increase of 10 per cent over that for August, 1928. Of this amount, 5,419,189,000 kw-hr. were made by fuels and the remainder, 2,840,237,000 kw-hr., by water power.

Low-Temperature Carbonization at Dunston, England

DETAILS OF THE DUNSTON POWER STATION OF THE NEWCASTLE-ON-TYNE ELECTRIC SUPPLY CO., WHICH UTILIZES LOW-TEMPERATURE DISTILLATION IN CONNECTION WITH STEAM RAISING FOR THE PRODUCTION OF POWER

MANY SCHEMES for the solution of the carbonization of coal at low temperatures and the production of by-products have been offered, the majority of plants having for their object the production of a semi-coke suitable for household use or the recovery of oils and gases. At the Dunston Power Station of the Newcastle-on-Tyne Electric Supply Co., Ltd. the problem has been approached from a different angle and the carbonization plant has been arranged to form an integral part of the power station for the purpose of achieving two results: first, the production of motor fuel and other by-products and second, the more economical generation of electricity.

This plant, which utilizes the Babcock low-temperature distillation system of Babcock & Wilcox, Ltd., has been in continuous operation for a considerable period of time and the installation is now being enlarged. Originally the plant consisted of two 20-t. retorts feeding a combined boiler unit with a capacity of 18,000 lb. of steam per hour and two 30-t. retorts feeding a single boiler unit with a capacity of 30,000 lb. of steam per hour.

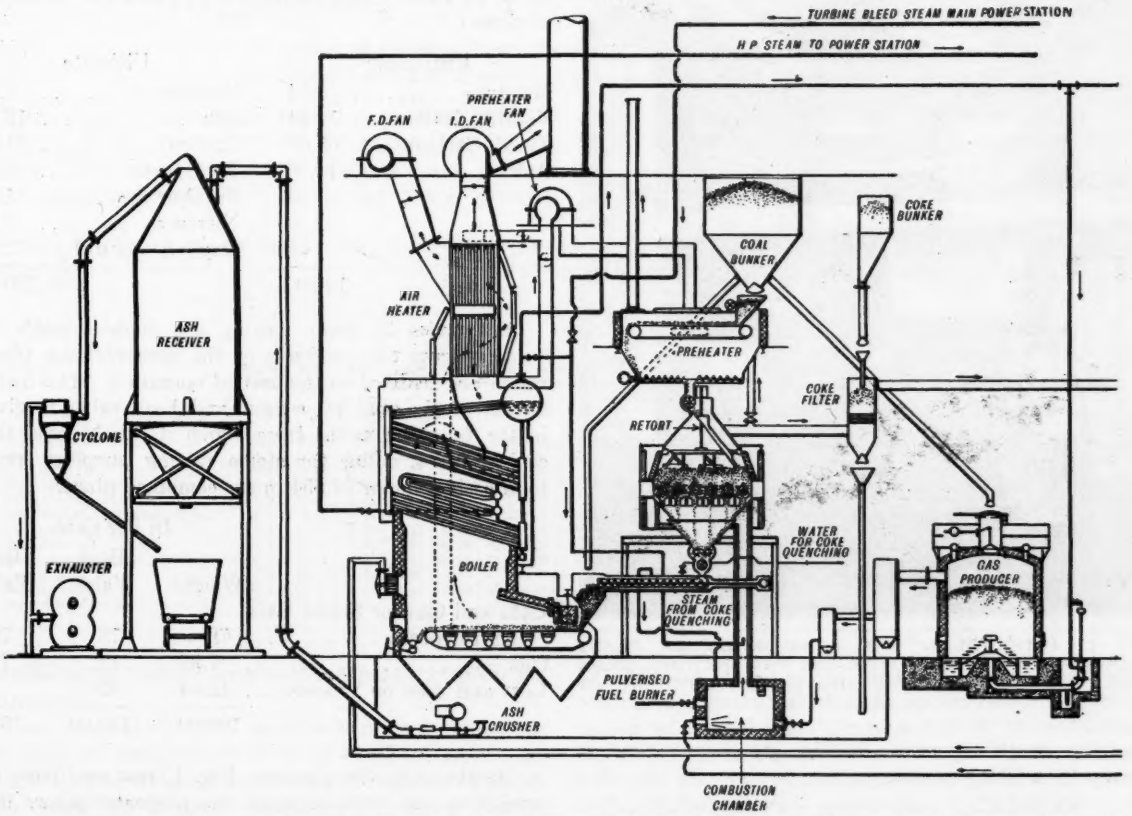


FIG. 1. BOILER ROOM CROSS SECTION SHOWING THE ARRANGEMENT OF EQUIPMENT IN THE BABCOCK SYSTEM. THE BY-PRODUCTS RECOVERY SYSTEM AND THE ELECTRIC GENERATORS ARE NOT SHOWN

Two smaller retorts with their boilers are now being dismantled to make way for a new retort of rectangular design which will have a through-put of 60 t. of coal per day.

It is intended that this new retort shall provide coke for the pulverized fuel boiler which stands in the same boiler house as the 30,000-lb. coke-fired unit.

The boiler now in service is rated 30,000 lb. per hr.,

has 5589 sq. ft. of heating surface, generates steam at 250 lb. per sq. in., 700 deg. F. total steam temperature and is arranged about as shown in the cross section, Fig. 1, has an interdeck superheater of 1944 sq. ft. heating surface, a standard tubular air heater with a heating surface of 10,960 sq. ft. and is fired by a standard Babcock & Wilcox LGM double chain grate stoker with a total area of 192 sq. ft. Both induced and forced draft fans are used. The 40-in. diameter, forced draft fan has a maximum capacity of 35,000 c.f.m. at 2.25 in. water gage and is driven by a 40-hp. motor. The 35-in. forced draft fan has a maximum

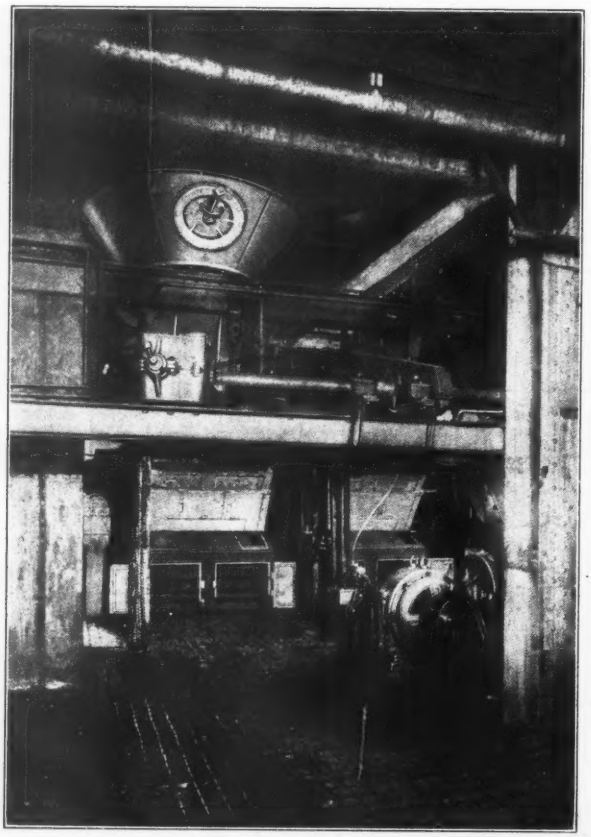


FIG. 2. INTERIOR OF THE DUNSTON BOILER PLANT SHOWING THE UNDER SIDE OF THE RETORT FROM WHICH LOW TEMPERATURE COKE IS DELIVERED DIRECT TO CHAIN GRATE STOKERS

capacity of 16,500 c.f.m. at 5-in. water gage and is driven by a 30-hp. motor.

Boiler Fired by Screenings Carries Peak Loads

In addition to these boilers, there is a pulverized fuel boiler with a capacity of 30,000 lb. of steam per hour, fired with pulverized fines obtained by screening the coal delivered to the retorts. This arrangement is convenient, as the coal contains a high percentage of fines and this pulverized fuel boiler can carry the peak load and enable a constant load to be carried on the coke-fired boiler so as to maintain a constant through-put of the retorts.

This pulverized fuel boiler is set on one side of the boiler house and the coke-fired boiler on the other, with the retorts and carbonizing plant in the aisle between, where it is under the direct supervision of the boiler house operating crew. The by-product recovery plant and a tar distilling plant are housed in separate buildings.

Coal used is similar to that originally supplied for the power station boilers and is mined in the Northumberland collieries. The following analysis is typical:

Proximate Analysis		Ultimate Analysis	
Moisture	9.29	Moisture	9.29
Volatile Matter	30.83	Ash	10.89
Fixed Carbon	48.99	Carbon	66,58
Ash	10.89	Hydrogen	4.55
		Sulphur	1.15
		Nitrogen	1.17
		Oxygen (by diff.)	6.37
	100.00		100.00

The calorific value of the coal is about 11,570 B.t.u. per hr., while the semi-coke produced has a calorific value of about 11,800 B.t.u. per lb. and the following analysis:

Proximate		Ultimate	
Moisture	0.74	Moisture	0.74
Volatile Matter	14.24	Ash	19.33
Fixed Carbon	65.69	Carbon	71.64
Ash	19.33	Hydrogen	2.94
		Sulphur	1.54
		Nitrogen	1.52
		Oxygen (by diff.)	2.29
	100.00		100.00

Economies in steam raising are made possible by revenue from the products of the carbonization plant, which are credited to the cost of operation. The distribution of the coal by weight and heat value is given in the following table, from which it can be seen that coal worth a dollar for steam raising purposes has a total cash value of $1.554 in the combined plant.

	In Per Cent		
	Weight	Heat Value	Cash Value
Coke and Gas for Steam Raising Purposes	76	76	76
Oils	7.36	12	79.4
Loss and used on process	16.64	12	...
	100.00	100.00	155.4

As shown in the diagram, Fig. 1, raw coal from the bunker is sent down through the preheater where it is heated to approximately 260 deg. F. Fuel is in the preheater about 15 min. and is then delivered continuously to the retort by means of a screw conveyor through a rotary valve, acting as a seal between the retort and the preheater.

Coal Is in the Retort About 3 Hr.

This preheating is effected by direct contact with flue gases drawn from the outlet to the boiler, flues being arranged so that the waste gases are drawn from the inlet and outlet of the air preheaters in such proportions that the requisite temperature is maintained in the preheater. Coal sent to the retort is automatically

leveled and passage of coal through the retorts occupies a period of about 3 hr. The temperature of the retort is maintained in the neighborhood of 1000 to 1100 deg. F. by a mixture of steam and combustion gases from a small auxiliary combustion chamber located below the retort.

In this particular plant, the auxiliary combustion chamber is arranged to burn gas from a small producer shown at the left, although it can be arranged to burn pulverized coal or coke-oven gas as well. Products of combustion from the adjoining combustion chamber are mixed with low pressure steam as shown in the chamber or brick-lined duct so as to maintain proper the temperature in the retorts. Hot coke is discharged continuously through coke breakers to a rotary sealing valve and thence fed to a screw conveyor to the stoker hopper. Provision is also made for feeding coal direct to the bunker for emergencies or to carry peak load.

Gas which is distilled from the coal mixes with the distilling gases and the mixture is drawn off from the upper section of the retort by a gas exhauster and passed through a filter which cleans the gas of dust before it enters the water-tube condenser in which the tar vapors are condensed.

After leaving the condenser, the gas is passed through a tar extractor to remove the final traces of tar and then to washers where the gas is brought into intimate contact with wash oils where it is stripped of oil vapors and piped to the burners at the back of the boiler furnace. The calorific value of the gas as fired is about 80 B.t.u. per cu. ft. Steam generated is fed directly to turbines in the adjacent plant which supply electricity to the company's system.

In the unit now under construction, it is intended to grade the coke obtained from the new 60-t. retort and separate the larger sizes for sale as domestic fuel.

Reliability of Hydroelectric Units

Analysis of Outage Time with Respect to Age and Causes of Outage for 134 Hydroelectric Units of Over 5000 Kw.*

THIS report embodies the results of the fourth year's study of this subject by the Hydraulic Power Committee. The same restrictions upon age and size of units were continued from the earlier years, namely, installation in 1920 or later and a capacity of 5000 kw. or greater.

The fact that for 1927 records were contributed for 134 units, as compared with 95 in the 1926 report, indicates the encouraging increase in coöperation that has been noted of member companies operating eligible units from year to year. The units reported upon this year include 91 of the 95 in the 1926 report, 14 of which were installed during 1927 and 29 of earlier date than 1927, but for which no data had been previously contributed.

In the collection, tabulation and analysis of the data, no change has been made from the previous year's procedure. Also a complete definition and description of all the terms used having been made a part of the first report in 1924, it is believed unnecessary to repeat these. The 1927 records were contributed by 31 operating companies.

*From serial report of Hydraulic Power Committee, N.E.L.A.

Of the 134 turbines, 106 were of the vertical reaction type (non-propeller) with a total rating of 2,572,780 hp.; 9 of the horizontal reaction type (total rating 142,400 hp.); 11 of the impulse type (total rating 274,000 hp.), and 8 of the propeller type (232,000 hp.), making a grand total of 3,221,180 hp. and an average rating of 24,039 hp. Combined with these turbines were 114 vertical generators, having a total rating of 2,031,260 kw., and 20 horizontal generators, with a total rating of 288,450 kw.—grand total, 2,319,710 kw.

The range of the generator ratings is from 5000 to 52,000 kw., with an average of 17,311 kw.; that of the speeds from 90 to 600 r.p.m.; and that of the heads from 45 to 2381 ft. The range of head of reaction type units is from 40 to 909 ft.; while the impulse type units extend from 1108 to 2381 ft.

A table, not shown, lists the principal characteristics, by reference groups, of all of the units whose analysis has been included in this report. The operating records for the year 1927 were tabulated by reference groups. In Table I, the records of the units of each type are summarized and compared with the corresponding summaries for 1924, 1925 and 1926 and with a summary of

TABLE I. SUMMARY OF OPERATING RECORDS OF HYDROELECTRIC UNITS COMPARED FOR YEARS 1924 TO 1927

	1924			1925			1926						1927						Steam Units, 1925
									Reaction Wheels						Reaction Wheels				
	Impulse Wheels	Reaction Wheels	Total	Impulse Wheels	Reaction Wheels	Total	Propeller Wheels	Impulse Wheels	Vertical	Horizontal	Total	Total	Propeller Wheels	Impulse Wheels	Vertical	Horizontal	Total	Total	
1. Number of units included	1	20	21	7	36	43	4	12	73	6	79	95	8	11	106	9	115	134	191
2. Average generator rating, kw.	17,500	16,210	16,270	16,786	16,614	16,642	24,750	15,229	14,800	10,000	14,435	14,970	21,825	17,614	17,523	10,522	16,975	17,311	29,460
3. Service time, %	61.2	77.06	76.30	78.05	81.32	80.79	82.18	80.50	69.51	81.98	70.46	72.22	80.50	84.24	73.06	78.70	73.50	74.80	65.08
4. Idle time, %	38.8	22.94	23.70	21.95	18.68	19.21	17.82	19.50	30.49	18.02	29.54	27.78	19.50	15.76	26.94	21.30	26.50	25.20	34.92
5. Outage time, %	6.5	7.37	7.32	1.84	4.42	3.99	11.28	2.30	3.05	4.43	3.15	3.45	14.84	3.87	2.89	1.78	2.80	3.58	13.36
6. Outage time when in demand, %	0.0	1.03	0.98	0.79	1.92	1.73	2.02	0.80	1.01	0.91	1.01	1.08	10.38	0.60	0.65	0.77	0.66	1.23	3.34
7. Outage time when not in demand, %	6.5	6.34	6.34	1.05	2.54	2.29	9.26	1.50	2.04	3.52	2.15	2.37	4.46	3.27	2.24	1.01	2.14	2.35	10.02
8. Reserve time, %	32.3	15.57	16.38	20.11	14.26	15.22	6.54	17.20	27.44	13.59	26.39	24.33	4.66	11.89	24.05	19.52	23.70	21.62	21.56
9. Demand time, %	61.2	78.09	77.28	78.84	83.26	82.62	84.21	81.29	70.53	82.89	71.47	73.31	90.88	84.84	73.71	79.47	74.16	76.03	68.42
10. Maximum possible service time, %	93.5	92.63	92.68	98.16	95.58	95.01	88.72	97.70	96.87	95.57	96.77	96.55	85.16	96.13	97.11	98.22	97.20	96.38	86.64
11. Capacity factor, %	14.4	46.14	44.43	24.61	51.49	47.44	68.25	50.52	50.37	46.19	49.74	50.62	59.60	52.10	54.46	53.80	54.41	54.53	44.35
12. Output factor, %	23.5	59.88	58.24	31.53	63.32	58.51	83.05	62.64	75.10	56.55	73.38	72.43	74.90	61.94	74.83	69.00	74.37	73.38	68.14
13. Service demand availability factor, %	100.0	98.21	98.30	99.04	97.84	98.04	97.60	99.11	98.12	99.17	98.19	98.28	88.46	99.21	99.26	99.21	99.25	98.60	95.16

TABLE II. AVERAGE OUTAGE TIME CLASSIFIED BY YEAR OF INSTALLATION

Year Installed	1927 Data			1926 Data			1925 Data			1924 Data		
	Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %		Number of Units	Average Outage Time, %	
		Total	In Demand		Total	In Demand		Total	In Demand		Total	In Demand
1920	4	1.49	0.22	4	3.04	0.19	3	3.19	0.20	4	3.63	0.55
1921	14	3.20	0.48	11	1.99	0.95	7	2.74	1.37	5	12.39	2.27
1922	14	2.18	0.25	9	1.15	0.20	9	3.98	2.07	5	1.88	0.64
1923	14	5.55	2.44	15	4.28	1.33	7	5.46	0.73	6	10.33	0.65
1924	33	2.80	0.90	25	4.20	1.42	13	2.36	0.08	1	0.80	0.80
1925	22	3.49	0.05	22	2.72	0.55	4	9.63	9.43	....	....	....
1926	19	1.39	0.19	9	5.34	1.82	....	....	....	....	....	....
1927	14	8.96	6.11	....	....	....	....	....	....	....	....	....
Total	134	3.58	1.23	95	3.45	1.08	43	3.99	1.73	21	7.08	1.02

steam unit reliability records for the year 1925, taken from a serial report of the Prime Movers' Committee on Turbines, N.E.L.A. Pub. No. 267-78.

The range of outage time percentages for 1927, except for one unit which is far out of line, are quite comparable with those of previous years; namely, from 14.77 per cent to 0 for the total outage time; and for the outage time in demand, 14.59 per cent to 0. . The extremely high outage time percentages of the one unit mentioned are due principally to the reduced base upon which they are computed, this unit having been installed late in 1927. Of the 80 reference groups, 31 are noted as having 0 outage time in demand.

The outage time percentages, both total and in demand, have been plotted for each individual unit against the year of installation. Neither installation nor least squares analysis of the data indicated any relation between age and outage time of magnitude comparable with the division of the individual units from the average. This result provides further confirmation of the conclusions reached from study of the earlier data on this relation.

Table II contains the outage time percentages averaged according to year of installation for the years 1924, 1925, 1926 and 1927.

Analysis in total by reference groups and causes of outage of the total outage hours were summarized into classes according to turbine type with the per cent of the total outage time resulting from each case in Table III.

For all of the classes of units in Table III, the most important principal group of causes of outage time is waterwheels and auxiliaries. The next in order is generators and appurtenances and the last, general hydraulic causes.

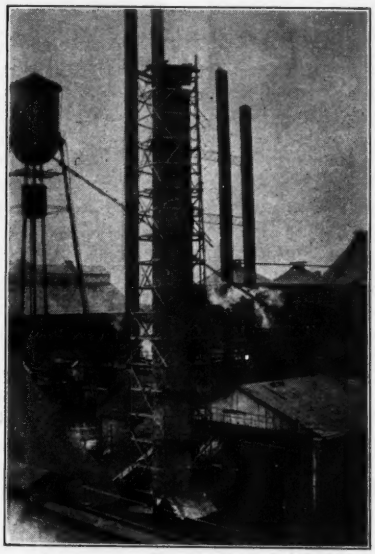
Of the individual causes affecting the outage of the entire number of units, headgates or intake is the largest item of general hydraulic causes, with other general hydraulic causes following. In the water wheels and auxiliaries group, the leading place goes to the runner, with general overhauling and replacements second. Cleaning and other causes respectively hold first and second places in the group of generators and appurtenances.

TABLE III. ANALYSIS OF CAUSES OF OUTAGE IN PER CENT OF TOTAL OUTAGE TIME, 134 UNITS, FOR 1927

	Propeller Type	Impulse Type	Horizontal Reaction Type	Vertical Reaction Type	All Reaction Type	All Units
Number of units included	8	11	9	106	115	134
General Hydraulic Causes:						
Ice or trash	1.87	0.90	0.45	2.69	2.57	2.32
Floods	....	....	....	3.13	2.97	2.29
Penstock or canal	...	4.82	3.84	1.22	1.36	1.52
Headgates or intake	1.14	1.95	0.40	5.97	5.68	4.70
Other general hydraulic	....	0.44	3.37	0.35	0.50	0.43
Total general hydraulic	3.01	8.11	8.06	13.36	13.08	11.26
Water Wheels and Auxiliaries:						
Runner	0.95	12.94	....	21.59	20.47	17.14
Shut-off valve	....	9.29	0.70	0.76	0.76	1.50
Turbine gates or needle nozzle	0.67	1.77	0.93	1.55	1.52	1.43
Guide bearings or main bearings	3.87	....	0.26	7.74	7.35	6.16
Thrust bearing	....	....	0.13	0.59	0.56	0.43
Governor and governor system	5.64	1.88	5.72	0.91	1.16	1.82
Pressure regulator or deflectors	....	1.27	0.57	3.96	3.79	3.04
Draft tube	34.88	0.79	0.86	1.22	1.20	5.63
Lubrication system	0.06	....	1.94	6.94	6.68	5.15
Vibration	....	....	....	1.38	1.31	1.01
Seal rings	....	....	0.77	2.57	2.48	1.91
Inspection	6.24	4.35	11.75	5.51	5.83	5.74
General overhauling and replacements	0.21	31.13	40.76	9.33	10.96	11.52
Other causes	25.11	0.15	11.41	3.89	4.28	6.63
Total water wheel	77.63	63.57	75.80	67 94	68.35	69.11
Generator and Appurtenances:						
Vibration	....	....	....	....	....	....
Lubrication or oil leakage	0.99	....	0.57	3.49	3.34	2.70
Rotor or field	2.52	2.39	2.14	0.35	0.44	0.91
Armature iron or windings	....	12.78	....	1.66	1.58	2.47
Exciter and rheostats	0.34	0.01	0.73	0.88	0.87	0.71
Ventilation system	2.00	....	2.79	0.77	0.87	0.94
Cleaning	8.69	1.30	2.64	7.18	6.95	6.62
Inspection	2.15	0.34	4.27	0.59	0.78	0.92
Other causes	2.67	11.50	3.00	3.78	3.74	4.36
Total generator	19.36	28.32	16.14	18.70	18.57	19.63
Total—all causes	100.00	100.00	100.00	100.00	100.00	100.00
Total outage time in per cent of total time	5.73	3.62	1.78	2.88	2.79	3.07

Low Cost Stack Razing

MANY COST ITEMS of constructive and destructive work are exceedingly hard to estimate with any accuracy. The element of risk is so great that an estimator often increases his figure in order to play safe.



SCAFFOLDING USED FOR RAZING A STACK WHERE THROWING OR DYNAMITING IS BARRED

Destruction of a reënforced concrete smoke stack, which stood in the path of progress and which, due to its location, could not be thrown or dynamited, presented itself as a problem to the managers of a large cotton oil mill. New boilers with an improved type of draft were to be installed so that the old stack, which was 110 ft. high and over 10 ft. outside diameter at the base, could not be used. Bids for razing the stack, ranging from $750 to $1500 were received from various contractors. The manager finally decided to do the work himself, using mill helpers to build the scaffolding and the mill truck to haul away the debris. Aid of helpers from a local boiler works, who were accustomed to working high up in the air, was sought and three were hired at 75 cents an hour to break in the wall. They carried their own liability insurance.

While the scaffolding was going up, a large hole was cut in the wall near the ground and a stopping chute extending into this hole was built to catch the debris as it fell from the breakers above. The scaffolding was built of 4 by 4-in. lumber, as it had been found that 2 by 4-in. lumber would not support the platforms.

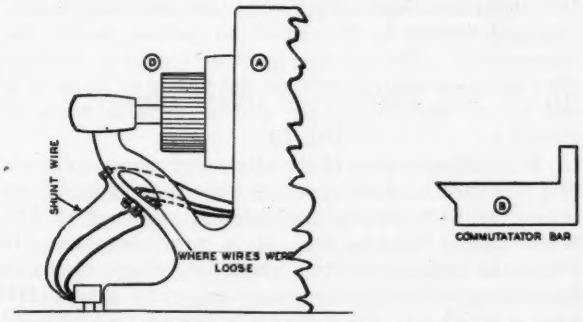
Scaffolding lumber at a cost of $130 was used but only $65 charged to the job. One hundred pounds of nails were also used. The time of truck and driver at $5 a day was charged to the job and the time of the carpenters and other helpers of the mill was added at their regular rates. After the stack was reduced to 50 ft., a fourth man was put on the scaffold.

The total time required was 16 days of 10 hr. each, 11 days of which were used for breaking in and for cleaning up the mess. Bids submitted had not included cost of carrying off debris. The labor, including the $0.75 per hr. men, truck and helpers, cost the job $473, which is considerably lower than the lowest bid.

Memphis, Tenn. W. D. BROWNING.

Loose Exciter Connections Cause Operating Troubles

IN OUR PLANT is a 15-kw., 125-v., 525-r.p.m., direct-current generator which is used for exciting the field coils of a 250-kw., 3-wire, 3-phase, 2300-v., 200-r.p.m.,



A. SKETCH SHOWING LOCATION OF WIRES THAT LOOSENED AND CAUSED TROUBLE. B. SHAPE OF COMMUTATOR BAR NOW USED ON EXCITER

alternator. When first purchased and installed, the commutator had the mica undercut. The exciter ran for about 3 yr. without any serious trouble except that the slots between bars had to be cleaned out about twice a week to prevent arcing between the bars and, when the load on the alternator would become 150 kw. or over, we had to cut back on the field rheostat of the exciter or the voltage would go clear beyond the voltmeter range

and the needle would hit the case. We have a Tirrill voltage regulator to take care of the regulation of the alternator.

About 8 yr. ago, the commutator bars rose up, all at once and, before the engine could be shut down, the brushes were nearly torn off the machine. The commutator was repaired and ran for a short time but a similar trouble soon developed. Again it was repaired but this time the commutator was turned down smooth, the idea being that the speed was too low for an undercut machine. About this time, a commutator stone was purchased and the commutator dressed when required.

Still the exciter voltage would increase when the load on the alternator ran over 50 per cent of rating and the exciter commutator would heat up so that shellac used on the wiring would be thrown off. At least the wires melted loose where they were soldered to the commutator bars, at three points 120 deg. apart. Some coils had to be replaced, several shorts being found in the commutator, and things seemed to be in pretty bad shape. The machine was repaired again and put back in service, after which it ran properly except for a tendency to heat and run over voltage as mentioned before.

One day while I was wiping up around the frame, I lifted one of the wires to wipe the frame underneath when suddenly I saw a flash of light where the wire goes through the frame. The frame is hollow and has an open space at the commutator end large enough to permit the hand to enter and operate an 8-in. wrench in order to tighten up the nuts on the studs which go through the frame. These studs have sleeves around them with mica washers under the nuts and washers on both the outside and inside of the frame. Lugs, soldered on the wires, are fastened on the studs by means of nuts and washers.

The flash was caused by the wire becoming loose in the lug. On taking the lugs off and examining them, it was found that they had never been well soldered and part of the lug was filled with what resembled rosin.

Wires and lugs were then cleaned and resoldered so that they were tight. They were then replaced in position and tightened, after which no further trouble was experienced. The machine now gets slightly warmer than the room temperature but not nearly as warm as it did before and the exciter voltage remains where it should be.

With all resistance of the alternator rheostat cut out and the exciter rheostat set so that the voltage of the exciter is 80 when the generator is carrying 20 kw., which is our lighting load, it is now unnecessary to touch the exciter rheostat, when the voltage regulator is working, unless the load on the generator exceeds 200 kw., at which time the exciter rheostat has to be turned back slightly to keep the exciter voltage at or below 125.

Harder brushes were substituted for the old ones. These new brushes seem to cut the mica down better than did the old ones and no trouble has arisen since the resoldering of the connections.

Twice to three times a week, the commutator is blown out compressed air to keep the winding clean and remove dirt from between the openings at D in the sketch. The commutator bars are now made as shown at B.

Minneapolis, Minn. FRED S. RUTLEDGE.

Boiler Beams Burned as Result of Poor Protection

WHILE REPLACING the brick work in the furnace of our No. 1 boiler, I found the 12-in. I beam column between the No. 1 and No. 2 boilers to be badly burned. After blocking up the front end of the boiler and removing brickwork, the condition of the I beam was found as shown at I in Fig. 1. After removing the brickwork in furnace No. 2, the web of the I beam column could be broken out with a small hammer, as shown at I, Fig. 2.

The three 7-ft. h.r.t. boilers formerly were set with 12-in. I beams for outside the boilers and between the Nos. 1 and 2 boilers. Two 16-in. I beams across the top supported the No. 1 boiler and two 18-in. I beams supported the Nos. 2 and 3 boilers.

FIG. 1. CONDITION OF I BEAM OF BOILER NO. 1 AFTER BEING BURNED OUT DUE TO POOR PROTECTION

FIG. 2. BLOWS FROM A LIGHT HAMMER WERE SUFFICIENT TO BREAK OUT WEB OF I BEAM OF BOILER NO. 2 AFTER IT HAD BEEN DESTROYED BY HEAT

New 10-in. H beams were installed for columns outside of the No. 1 and No. 3 boilers, replacing the old burned out I beams and two 20-in. I beams replaced the others for supporting all three boilers. An air space had been designed to surround the beams but loose mortar had filled these spaces reducing the insulating effect and causing overheating. From this experience, it would seem wise to inspect, occasionally, all columns and beams enclosed by boiler brickwork.

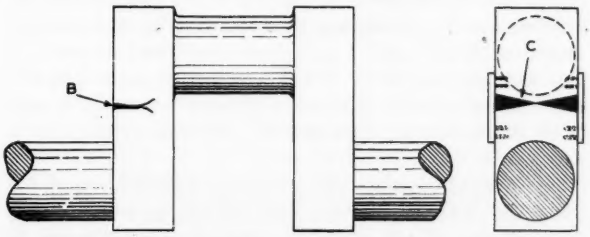
Waltham, Mass. R. B. ROWE.

RAILROAD ELECTRIFICATION, which began in 1895, closed the year of 1928 with 1753 route miles electrified. Three important projects have been completed during the past year; the Great Northern's Cascade Tunnel, suburban routes of the Pennsylvania near Philadelphia and the narrow gage system of the Boston, Revere Beach and Lynn. Projects announced are the Pennsylvania lines from New York to Wilmington, the Reading around Philadelphia and possibly to New York, Bethlehem and Reading, the Lehigh Valley between Mauch Chunk and Wilkes-Barre, the Delaware, Lackawanna and Western its suburban lines near New York. Faster and more frequent service, enhancement of real estate values and elimination of smoke and noise in urban and suburban areas are the chief considerations.

Shaft Welded in Place Preserves Alinement

SUCCESSFUL REPAIR of a 200-brake horsepower engine crankshaft was made, as indicated in the accompanying sketches, by means of electric welding.

Extending almost through the web, the crack was such that the shaft could not have been lifted out of its bearings without breaking it apart. The crack, shown at B, was in the No. 2 web. Nos. 1 and 2 rods were therefore dismantled and the crankpin on No. 2 crank



CRANKSHAFT CRACKED ACROSS FACE OF WEB AS SHOWN AT B IS REPAIRED BY ELECTRIC WELDING IN LAYERS AS SHOWN AT C

was covered with asbestos rope in order to protect it from the heat. The shaft bearings were then tightened to keep the shaft in alinement.

By means of an oxy-acetylene cutting apparatus, a vee was cut in at one side and extending halfway through the web so that the cracked portion was cut out. Metal was built up in this vee to a height of 1¾ in. by the use of an electric welding device, the filler rod being composed of vanadium steel. A vee was then cut in the opposite side of the web until the formerly deposited weld metal was reached. This second vee was filled, as in the former case, by electric welding.

In making the welds, the steel was built up successively in ½-in. layers until the vees were entirely filled. The sides of the web were then filed flat and two 1⅛-in. steel plates were fitted to the sides of the web. After screwing these plates to the web, the screws and edges of the plates were welded over as shown at C.

After completing the welding process and loosening the bearings, the shaft ran as before. The repair was entirely satisfactory and no overheating of the parts occurred.

Brentford, England. W. E. WARNER.

Retain Ideas by Jotting Them Down

MANY IDEAS occur to a wide awake engineer and many interesting kinks come to his attention during his daily occupation but often they are forgotten, at least in detail, by the time they can be written up as a magazine article. Shortly after I started to offer such ideas to publishers, whenever I came across a thing which I thought worth while, I started to jot down details in a note book which I carried in my coat pocket. The notes and sketches were made in a hurry with a lead pencil and soon became hard to read because they became dirty or smudged.

If not promptly recorded, valuable and unusual information about unique kinks is thus often permanently lost. Memory has its limitations and one should use some means to make a record for future reference. I have made the habit for some years of carrying a loose leaf note book supplied with squared paper. I make a pencil sketch of any kink I consider worth while on the ruled paper and written notes on the other side. Then, when I have time, I can write an intelligent description of the idea or kink and offer it for publication. This has become a habit that has been valuable to me and I would advise others to get the loose-leaf note book habit.

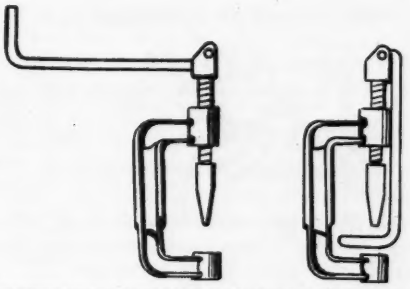
Toronto, Canada. JAMES E. NOBLE.

Powerful Rotary Belt Punch

FOR THICK BELTS, especially those made of canvas, balata, or hair which are laced with heavy lacing or on which heavy fastenings are used, the rotary belt punch illustrated gives excellent service.

In using this punch, it is necessary only to turn the crank and the punch is slowly but powerfully forced through the material. A hole as large as ⅝ or ¾ in. in diameter is cut with utmost ease and precision.

The distance from the punch to the inside of the frame is such that the frame serves as a guide for



PUNCH SHOWN IN POSITION READY FOR USE AND FOLDED FOR CONVENIENCE IN HANDLING AND STORAGE

punching holes at the correct distance from the end of the properly squared off belt, thus assuring perfect alinement. By means of a lateral spacing attachment, the distance between the holes is made uniform. Punches of various sizes may be used as desired.

Newark, N. J. W. F. SCHAPHORST.

Trouble from Governor Pin Wear Avoided

IN REFERENCE to the article on Governor Pin Wear published on page 916 of the August 15 issue, I have a 12 by 12-in. engine running 300 r.p.m. We make a practice of making new bushings and pins, if needed, every year. The expense of replacement is small but it avoids all trouble such as was described in the above-mentioned article.

Waltham, Mass. R. B. ROWE.

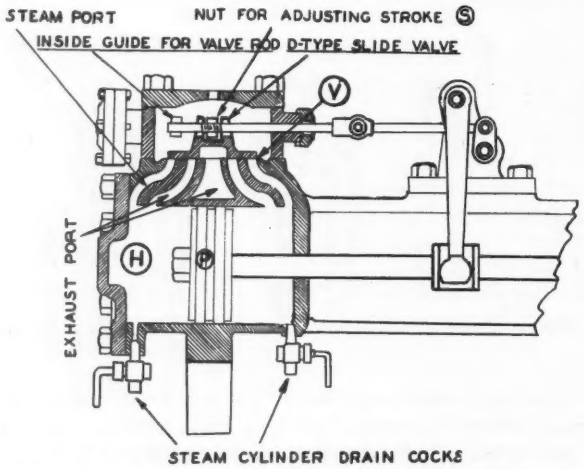
POWER PLANTS vary with the design for different load conditions, average prices being $85 per kilowatt of capacity for peak load station, $100 per kw. for standard system load plants and $115 per kw. for base load plants. Estimates of steam accumulator turbine plants for peak load service run $55 per kw. of capacity exclusive of the accumulator and $17 per kw. of maximum changing capacity for the accumulators and piping making a total of $72 per kw.

Questions and Answers

Duplex Pump Valve Action

IF, IN STARTING a duplex steam pump, one piston strikes the head, while the piston in the other cylinder does not move at all, what is the trouble and how may it be corrected? M. L. S.

A. Action described will occur if the valve is not set correctly. When the piston P is at the end of stroke in one cylinder, say at H in the illustration, the valve on the companion cylinder should be so set, allowing sufficient clearance, that the steam port for the return



PROPER RELATIVE POSITION FOR DUPLEX PUMP PISTON AND OPPOSITE VALVE WHEN VALVES ARE PROPERLY SET

stroke will be slightly open as at V and its piston then will be forced by the steam to move toward the head end of that cylinder.

Duplex pump valve setting is best accomplished by first determining the central position of the steam piston. Drive it to one end until it strikes the head and mark on the piston rod a point corresponding to some permanent reference point such as the face of one of the stuffing-box glands; then force the piston against the opposite head and again mark the position on the piston rod. Divide the distance between these two marks and bring the piston to its central position by placing the middle mark on the rod opposite the reference point.

When one piston is in its central position, the valve of its companion steam cylinder should be also in central position and slight steam openings should be found at each end of the valve. Correction is made by moving the adjusting nut S. When the valve and piston are in these positions, the rocker arms should be in a vertical position. After one set of pistons and valves has been adjusted, the other set should be adjusted in like manner.

Effect of Generator Speed Reduction

OWING TO a condition that can not be remedied at this time of the year, I have had to reduce the speed of the engine, which is direct connected to a 130-kw. alternating current generator, from 257 to 252 r.p.m. Will this affect or damage the generator or motors in any way?

2. Would running the generator under no load for a length of time with the main switch and breaker in service cause overheating, burning or other damage to the generator? C. G. H.

A. The only appreciable effect of reducing the speed from 257 to 252 r.p.m. would be to reduce the frequency. This would reduce the speed of synchronous motors, if you have any on the line.

2. Running the generator under no load would cause no damage whatever.

Steam Turbine Lubrication

HOW OFTEN should the lubricating oil in a steam turbine which is running 50 hr. a week at 3600 r.p.m., be changed? I noticed that the oil in my turbine foams and I think it has not been renewed for 4 yr. J. B.

A. Lubricating oil used in a steam turbine should be renewed every year. It should be filtered every 3 or 4 mo. Many large plants renew part of the oil every week. The conditions of renewal depend upon local conditions of operation as well as upon the particular oil used.

Action of Superheated Steam

WE HAVE a boiler whose pressure, 225 lb. per sq. in., is reduced to 175 lb. at the throttle of the engine it serves. If the steam is superheated by the pressure reduction and if superheated steam has greater expansive qualities than saturated steam, why is a bypass valve used to get boiler pressure on the main engine when desiring full power? Is this procedure necessary? J. C. C.

A. One of the primary objects of superheating by adding heat to steam at constant pressure, is to permit the steam to expand lower in pressure than it otherwise could without the formation of condensate. Assuming the steam to be dry and saturated at 225 lb. pressure, the steam at 175 lb. pressure would not expand to a lower pressure than that at 225 pressure without formation of condensate. The final pressures in each case would be the same. More work, however, would be done by expanding the steam from the higher pressure as the area of the diagram under the expansion line would be larger in this case.

A.S.M.E. Fuels Division Meets at Philadelphia

WORK AND TRAINING OF THE FUEL ENGINEER, COMPARATIVE VALUE OF DIFFERENT KINDS OF FUEL, FUEL PREPARATION, SMOKE ABATEMENT AMONG PROBLEMS DISCUSSED AT ANNUAL MEETING

OPENING with a good attendance from all sections of the country, the third annual meeting of the Fuels Division of the A. S. M. E. was happily connected to its location, Philadelphia, by Chairman V. J. Azbe, who had discovered that Benjamin Franklin was one of the earliest fuel engineers. Mr. Franklin wrote essays over a period of 1762 to 1785 on the cause and cure of smoking chimneys and was even called to England as an expert on heating and ventilation of some government buildings which were causing trouble.

In his opening remarks, Mr. Azbe emphasized how much there was to be accomplished by fuel engineers in the way of increasing economy in the use of fuels as well as decreasing annoyance and expense from the products of combustion escaping to atmosphere. Spite of all the progress made, there are yet greater problems to solve.

Doctor R. H. Fernald, in his address on the Work and Training of the Fuel Engineer, carried this thought into detail. Of the fuels used in the world, ½ the solid and ¾ the liquid are produced and used in the U. S. A. and because of the variety of fuels and their uses there is great need for trained fuel engineers to promote economic utilization and conservation, while few such engineers with adequate training are available. This need will continue for, spite of popular misconception, fuels must always be the great source of energy. Water power, the other source, meets only 10 per cent of the light and power demand of the country and a negligible amount of heat. Even when all the water power that can be utilized is harnessed, it will meet only seven to eight per cent of the demand which will have arisen by that time.

In many establishments, proper fuel engineering has changed the profit and loss balance from red to black and the ramifications of fuel economics are shown at oil stills where coal, oil or gas is used interchangeably as fuel according to the supplies available and market prices. Among coming developments are home heating for greatest comfort and convenience by oil, gas or central plant steam according to conditions; probably home cooling as electric refrigeration expands, and other features not now even dreamed of.

To meet these problems, the fuel engineers must have thorough grounding in Physics, Chemistry and Thermodynamics and their applications to fuel utilization, heat conservation, smoke prevention, as well as the relation of these problems to public welfare and national prosperity.

PULVERIZED COAL VS. GAS OR OIL

Monday afternoon, two sessions were held, one devoted to pulverized coal, gas and oil as fuels, the other concerned, with heating problems of houses and apartments. At the latter the points of difference were taken up between the domestic heating problem and industrial use of heat, also application of stokers for heating boilers. Inadvisability was pointed out of putting a stoker under a boiler not properly designed and which could not absorb the heat which the stoker can produce.

Relative economy of pulverized coal, oil and gas as boiler fuels were discussed by Martin Frisch, whose paper will be abstracted later.

Discussing the Sampling of Pulverized Fuel, Horace C. Porter commented on the difficulty of getting a representative sample on account of the zoning of density of fuel and of velocity in a pipe in which air is carrying fuel. Larger particles tend to hug the walls. It is, therefore, necessary to take samples from various parts of the pipe and for varying lengths of time but accurate determination of where or how long has not yet been made. Sampling should be in a vertical pipe at a point as far as possible from disturbance of fans or mixers and at a distance of several pipe diameters from any elbow, branch or other irregularity in the pipe. Samples should be taken at several places in the piping system and mixed.

In discussion, the question was raised as to how far it is well to go to get an exact sample when a relatively close sample serves for practical purposes but it was argued that it is important in determining mill performance since unnecessary fineness adds to cost of pulverizing. Air control of mills seems to tend to reduce the percentage of superfines and screen control to increase it.

Experience was that for lignites 50 to 55 per cent through a 200 mesh screen, for Illinois coals 60 to 65 per cent, for eastern bituminous 75 to 77 per cent and for river anthracite 80 to 85 per cent gives satisfactory combustion. Excess of superfines is found to give trouble in causing fly ash.

COAL PREPARATION, STOKER PROGRESS AND INDUSTRIAL HEAT USES

Tuesday's sessions covered these topics with papers dealing especially with anthracite preparation, a low temperature distillation process, gas, oil and electricity for industrial heating, fuel uses in ceramics and cement manufacture and recent developments in stoker design. The last named subject was presented by H. D. Savage, president of the Stoker Manufacturers' Association, as a collaboration of material furnished by the manufacturers.

It was shown that some 60 per cent of the water-tube boiler horsepower of the country is stoker fired and has been since 1923. Development is toward increased size and capacity, several multiple retort units being projected or in use up to over 700 sq. ft. projected area and in England chain grates going up to 700 sq. ft. Combustion rates for continuous operation are being increased. Factors involved are air distribution, speed of mechanism and fire thickness. Some use a longer retort, some a deeper retort and some greater overfeed.

Rates as high as 75 lb. per sq. ft. per hr. are being attained on underfeed and up to 60 lb. on chain grates. Chain grate speeds have been increased to 60 ft. an hr. for bituminous and 100 ft. an hr. for anthracite.

Preheated air has necessitated provision for structural expansion and for larger air openings in tuyeres, but tendency of certain coals to fuse into a mass has limited air temperature to around 300 deg. F. Where fusion is not encountered, 350 deg. is deemed safe without excessive maintenance cost of grate surfaces.

Single retort stokers for 200 to 600 hp. are developing of screw type for heating and of ram type for power, both coal feed and a small fan being driven from one motor.

In discussion, double end stokers were advocated by R. A. Forsman because of shorter fuel travel, better reflection of heat, mixture of volatiles from ends with air in the center, responsiveness to varying loads, great capacity and elimination of expensive bridge wall. He felt that stokers must come to give their highest economical combustion rate continuously and be able to operate over 6-month periods without taking out of service; also, that more attention should be given to clean and neat appearance.

J. S. Bennett called attention to work done in substituting larger stokers for smaller ones in old installations with gains up to 13 per cent in efficiency and 60 per cent in capacity of the boiler unit. Also to European development where stokers have to take any kind of fuel as it comes, one of the largest being in Berlin where all kinds of fuel are burned on one stoker.

Anthracite Coal Preparation

Speaking on the use of anthracite silt and culm, Frederick H. Dechant defined silt as the small sizes, 3/32 in. diameter to dust, resulting from wet preparation of standard sizes, some 9,000,000 t. being produced annually, containing 25 per cent non-combustible matter. Culm is the refuse from former dry preparation and exists as huge banks which may or may not contain valuable amounts of coal. There now exist some 92,085,000 t. of culm and 91,785,000 t. of silt, the latter rapidly increasing.

Reclamation methods are flotation in a heavy fluid mixture of the combustible, the refuse sinking, or a mechanical separation, with subsequent concentration of the coal sludge. Recovery of 95 per cent of the coal is practical by methods now developed, but only 14 per cent of the annual silt produced is now used. This is used for stoker firing, pulverizing or briquetting, that for stokers being caught by a 3/64-in. mesh screen which will catch some 30 per cent of the silt. This can be burned on chain grate stokers at 24 lb. an hour per square foot. Several plants use pulverized silt at heat release rate of 12,000 B.t.u. per cubic foot of combustion space per hour and 20,000 B.t.u. is possible. Briquets are as yet of minor consequence.

Investigations show that screened silt, refined to 15 per cent ash, at $3.27 per ton at the plant compares favorably with low-volatile bituminous at $3.92 a ton as stoker fuel. Pulverized silt may cost $4.47 a ton ready to burn, hence the pulverized fuel is more advantageous to producer of both coal and power. The screened silt can be sold in competition with bituminous for long haul shipping where it can be laid down at the power plant at a cost of 65 cents a ton lower than bituminous.

For the balance, 70 per cent, Mr. Dechant suggested the building of pulverizing and drying plants at central points in the anthracite fields and shipment of the pulverized coal in air-tight hopper cars. This would remove the cost burden of pulverizing plants from the power plants, making this fuel available for even moderate sized plants, and permitting the pulverizing equipment to be operated at high load factor. He estimated that the cost at the pulverizing plant would be $2.80 a ton and that it could be stored the same as larger sizes without hazard or deterioration.

Industrial heating might seem outside the realm of the power plant man except that he has to furnish the energy. Treating of the economics of this subject, J. A. Doyle brought out that the most important factor is the suitability of the form of heating to the industrial process rather than thermal efficiency or heat balance of the plant. Each form of heating has its useful field and the heat problem is to make as effective use as possible of the energy consistent with requirements of the process and maximum output of product of good quality and at minimum cost.

Convenience, ease of control, improvement of output are the important factors to the manufacturer. The power plant man must provide these first, then work for the best economy possible.

To meet these conditions, Henry O. Loebell urged the advantages of gas, urging the improvement of furnaces and adaptation to specific requirements in each case, also coöperation between maker and user of the furnace. He advocated the use of luminous flame to take advantage of radiant heat.

Claims of fuel oil were presented by Leod D. Becker and improvement in methods of control and in furnaces outlined. Make-shift installations are likely to disappoint and the advantages and limitations of oil should be considered when planning an installation. Oil fuel cannot correct for bad furnace design. Good burners are essential but not the only essential in the use of oil for industrial heating.

Coal Carbonization

This subject was considered in three papers. One by C. B. Wisner described the results of a process for making "coal balls" by a low temperature method, the product being so far used as domestic fuel, although possible as a power fuel if cost can be sufficiently reduced. One by Max Toltz detailed the Luigi process for production of carbon char which can be pulverized or briquetted from low-grade coal or lignite. The mine-mouth plant crushes, dries and carbonizes the fuel, carbonization being at 1112 to 1148 deg. F. Fines under ¾ in. are screened out for boiler fuel for the plant. Char of pea size results which is ground to ⅛ in., briquetted with pitch to egg size and sold for domestic use. The tar, after clarifying, is suitable for cracking into oils, creosote and paraffin. Pitch for briquets is derived from the tar but only to half the amount needed. One ton of char is produced from 2½ t. of lignite.

J. D. McQuade outlined a third process adopted to convert the 35 per cent of slack in mine operation into marketable fuel by the Hayes process. Two units, each

for 50 t. per 24 hr., are in operation. A tubular retort, 17 in. by 20 ft. is heated externally by gas and fuel moved through it by a screw conveyor which alternates forward and reverse motion, the former predominating. Carbonization by a total travel of 240 ft. in the retort, is completed in 25 min. at a rate of 700 lb. an hour. Resulting char is ground for briquetting.

Gas released is used for heating the retorts and for making steam. Fuel is crushed to ½ in. or less for the retorts. At the feed end, temperature is kept at 1400 to 1600 deg. and gives discharge temperature of 1100 to 1300 deg. F.

One ton of Illinois coal produces 1326 lb. of char, 30 gal. tar, 5000 cu. ft. of gas. The char is formed, with 10 per cent pitch into 2½ oz. pillow-shaped briquets at operating and fixed charges cost of $2.80 per ton input. Income from product is $5.05 per ton input. Installation is planned of a 400 t. per day plant.

Water Walls for Boiler Furnaces

Two papers were presented Wednesday morning, one by Ollison Craig on Economics of Water Wall Installation, the other by J. S. Bennett and P. N. Oberholtzer on Design of Water-Cooled Furnaces. The session aroused the greatest interest of any at the meeting and provoked much discussion. A resumé will be given in a later issue at greater length than is possible here.

Fouling of Boiler Heating Surfaces

At the same session, J. W. Pierson gave the results of experience at the Crawford Plant of Commonwealth Edison Co. with fouling of boilers on efficiency. Low grade Kincaid coal is used having 16.95 per cent moisture, 11.95 per cent ash and 4.04 per cent sulphur burned on chain grates, some of the furnaces with water-walls. Ash melts at 1950 deg. F. hence reaches lower tubes and superheater in a viscous state and adheres to the surfaces. Sulphur in the ash carried through to economizer and air preheater causes corrosion with resultant outages for repairs.

Thirty-two boiler units are installed of which 26 are needed in summer and 27 in winter to carry the load. Summer operation is for 35 days and winter operation 42 days, then 6 days out for cleaning. Soot is blown every 12 hr. and boilers are air or water lanced every fifth night. The first 14 units had two rows of tubes at 7-in. centers in the lower bank, the rest at 3½-in. centers. This gave too little room for hand lancing which is found necessary as a supplement to blowing. Later units have three tube rows on 12 in. centers, the rest 6 in. centers which allows of air lancing. The older units are water lanced with a ⅛-in. stream which cracks off the slag.

With the water-cooled furnaces, less slag is deposited on the tubes and is more easily removed.

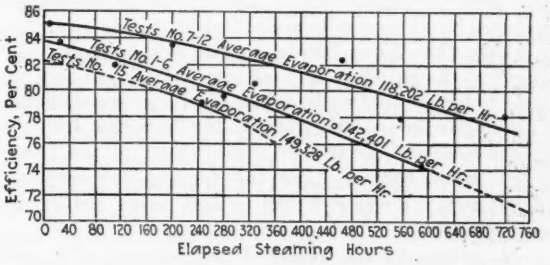
To determine the effect of fouling on efficiency, three series of tests were run at intervals of a week between tests. One series was at output of 118,000 lb. steam per hour, another at 142,000 lb. an hour and a third at 150,000 lb. an hour. Elapsed time as shown in the curves is steaming time only, since no fouling occurs during banked periods. The greater the output, the more rapid the deposit of slag so that after 590 hr. of steaming at 142,000 lb. efficiency was down to 74 per cent and after 300 hr. at 150,000 lb. the boiler could no longer maintain that output.

Consideration of the economics of heating where no power production or process heating is involved occupied the session of Wednesday evening. All types, from the use of low-grade fuels to electric current were treated in a comprehensive series of papers, which gave the status and advantages of coals, coke, oil, gas and electricity.

Outstanding was the feeling that the customer demand for cleanliness and convenience must be met, as well as to show reasonable cost. One point brought out in discussion was that, of all domestic heating, some 80 per cent is governed primarily by cost considerations, where the cheapest fuels will be used, hence the biggest problem is to develop the best methods of utilizing such fuels as to both boilers and furnaces for house and apartment building heating.

Effort to reduce the cost of electric heating by hot water storage during off-peak periods is one development which is being pushed.

Survey of coal-burning boilers to determine the causes of dissatisfaction, service to put heating plants


Efficiency, Per Cent
86
84
82
80
78
76
74
72
70
0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600 640 680 720 760
Elapsed Steaming Hours
Tests No. 7-12 Average Evaporation 118,202 Lb. per Hr.
Tests No. 1-6 Average Evaporation 142,401 Lb. per Hr.
Tests No. 15 Average Evaporation 149,328 Lb. per Hr.

DROP IN EFFICIENCY DUE TO FOULING OF BOILER BURNING ILLINOIS COAL

in proper condition and to keep them so and provision of automatic stoking and ash removal are developments in the anthracite industry which are bringing results. Under capacity in boiler or chimney or both has been found one of the chief defects. Use of mixed sizes of coal has been found to give seven per cent gain in efficiency over use of a single size and production of two mixed sizes of anthracite only was predicted as the probable result.

Saving of fuel by insulating the roof and walls of a house was shown to have been 10 to 30 per cent according to the first construction of the house and the exposure. While cost of insulation was not stated, it would seem that a saving of 20 per cent in fuel should give good return on the investment required besides giving a house cooler in summer as well as warmer in winter.

Smoke Abatement

Experience in several cities, Salt Lake City, Nashville, Knoxville, was summarized and commented on at the Thursday morning session and one method of smoke measurement and recording described at the afternoon session.

While conditions vary according to location, agreement was general that a slow steady process of education of the public to the needs and advantages of smoke elimination was preferable to drastic penalizing. Good coöperation is generally given if a conciliatory course is adopted. Better boilers and furnaces for house and building heating are needed but instruction of the user as to how to get best results can accomplish much.

Editorial Comment

Precision Among Professions

Undoubtedly the incentive to get a knowledge of the facts surrounding industrial conditions and to use these facts to develop bigger and better industries is the most common deciding factor in the choice of engineering as a profession. Mathematics is recognized as an exact science and is the engineer's corner stone. Other sciences such as physics, chemistry and psychology are also tools in the hands of engineers. Their laws cannot be said to be stated with 100 per cent accuracy but certainly no engineer would be considered a success if only 75 per cent of his solutions to problems were found to be correct.

It may not be fair to compare the legal profession with that of engineering in the matter of accuracy of decision but everybody must feel that this profession, probably the oldest known to the human race, has a long way to go when an eminent judge, pointing with pride to his record, made public the following statement: "An impartial investigation of the Superior Court decisions reviewed by the Supreme Court in the last six years shows that I have the highest percentage on affirmations. I was reversed in only seven out of nineteen cases."

In estimating the expected performance of a power plant still on paper, several thousand calculations must be made, a mistake in any one of which will throw the results out of line. Not only must the mathematical calculations be correct but the engineer's judgment of what can be expected from the operating staff will have an influence on the accuracy of his prediction, yet in plant after plant it will be found that the actual accomplishments vary by only a small percentage from those predicted by the engineers who designed the plant.

Accuracy is indeed an essential characteristic for success in the engineering profession and it seems strange that other professions have not fashioned implements and standards by which more precise results can be secured.

Water Power and Electricity Costs

Apparently the long drought suffered during the past season has done much to assist the general public in understanding the limitations of water power systems, the necessity for steam standby stations and the constant reiteration of engineers that steam stations should occupy first place in the general power supply system.

It is not easy for the average citizen to understand the indifference with which public utility officials view undeveloped water power sites and to reconcile millions of potential kilowatts going to waste at these sites with millions of pounds of coal being burned to produce power in nearby steam plants, while in periods of abundant water, idle steam standby stations appear to be the height of folly.

Local droughts in other years, notably in California, have increased the respect of the public for steam plants but this is the first time for many years that the lack of rain has affected practically the entire country.

For the first time since 1921, water power production during 1929 will probably fall below the level of the previous year. During the first 8 mo. of 1929 the output of water power plants has increased by only 2 per cent over a corresponding period in 1928 while the production of fuel burning plants has increased 18.5 per cent. Steam power will apparently carry the entire growth of the electrical industry.

Fortunately the strong reserve in steam standby stations and extensive interconnection has been able to carry the unusual load in spite of the relatively low output of water power plants. For instance, water power plants in Maryland operated at less than 12 per cent capacity during August.

Development costs of water power sites still available are high and the necessity for standby plants is so urgent that future projects can be justified only on a large scale and under such conditions of storage and system capacity as will allow the operation of baseload steam plants with the water power plants carrying the peak.

Columbus and the Egg

Many things which seem tremendously difficult at first are amazingly simple after somebody shows us how to do them. Usually when it becomes necessary to devise a new method or a new machine or device we think of the more complex arrangement first. This is not true universally, but in perhaps nine cases out of ten it is. Among the notable exceptions are the Edison screw-base lamp and socket and the safety match box. The screw base of the modern incandescent lamp today is the same as it was when Edison invented it 50 years ago and the safety match box with an open container sliding inside an outer casing never has been improved upon since two Swedish match makers devised it. In general, however, the evolution of a perfected device is from the complex to the simple.

An interesting example of this process of evolution is that which had its culmination in the Rectox rectifier described in this issue. The amazing simplicity of this device is striking, yet until it first made its appearance several years ago, all sorts of more complicated means were tried, none of which had the desirable characteristics of the Rectox.

Notwithstanding the widespread use of alternating current there are many applications for which direct current is more suitable than alternating current. Since only alternating current is available in most instances, a reliable device capable of converting alternating current to direct has long been sought for.

All of the early attempts to produce a rectifier were either mechanical or electrical in nature. Of course, in thinking of the conversion of alternating current into

direct or vice versa, the first thing that suggests itself is the motor generator principle. While the motor generator is a highly effective piece of electrical machinery, it is not, in the true sense of the word, a rectifier. This in itself is no objection to the use of the motor generator and it has long been the most reliable means of converting alternating to direct current, particularly where large powers are concerned. It has the disadvantage, however, of being expensive and requiring attendance.

Among the true types of mechanical rectifiers the rotary synchronous rectifier consisting of a commutator driven by a synchronous motor, has the most merit, although it has many undesirable characteristics which limit its use to certain applications. Mechanical rectifiers in general are suitable only for small power purposes.

Early in the search for a reliable rectifier it was recognized that the problem might be solved by a chemical method. It was discovered that when certain electrodes were immersed in suitable electrolytes films of gas were formed on the electrodes which permitted the passage of current in one direction but not in the reverse. A number of these rectifiers were developed but no great amount of success was ever attained. The chemical rectifier was subject to all the disadvantages possessed by any device incorporating the use of an electrolyte.

The first really good rectifier produced was the mercury arc type, employing the unilateral conductivity characteristic of the mercury vapor arc between metallic electrodes and a pool of liquid mercury. This rectifier was highly efficient and had greater capacity than any other rectifier developed. Its life was good although not indefinite and for certain purposes it was ideally suited. Again, however, this rectifier was expensive.

With the development of radio and the vacuum tube an entirely new type of rectifier made its appearance. This was the thermionic rectifier, exemplified by the Tungar and Rectigon and the Kenetron. These are excellent rectifiers and are admirably suited to many applications. During recent years they have received great attention and are used in all branches of the electrical art.

From the standpoint of simplicity a more simple form of rectifier than the vacuum tube could hardly be imagined, yet within the last five years a rectifier has been developed which is so absurdly simple as to make even the vacuum tube seem complicated.

This is the Rectox rectifier, consisting of nothing more than a stack of metal washers clamped firmly on an insulated support. Through this stack of washers, current passes easily in one direction but not in the reverse direction. Having no moving parts whatever, it operates without noise and being rugged it can withstand severe treatment without danger of being damaged. Its wave form is excellent.

While the Rectox rectifier may not be the final achievement in the development of this class of equipment, it is certainly a tremendous improvement over the complex contrivances of years ago. Looking at this simple device one wonders why nobody thought of it before. If this seems strange, however, it may be well to bear in mind the famous story of Columbus and the egg.

The Worm Turns

Gone is the old prejudice against American-designed Diesel engines. American engineers have demonstrated, finally, that they are capable of producing Diesel engines which are the equal of any in the world.

It is natural that gas and oil engine power should have received its earliest development in Europe where coal was scarce and therefore comparatively high in cost. Hence it was a quarter of a century ago, when large size internal combustion engines were introduced in this country, prospective manufacturers sent investigators to Europe to select a gas engine or later an oil engine to build under license in this country.

In the early nineteen hundreds, the required haste to supply a Buffalo plant with 40,000 hp. of gas engines —the largest gas engine power station of its time— obliged the builders to use foreign drawings without recourse to minor changes in design.

Later, due to the great developments made in steam turbines, boiler furnaces and steam plant auxiliaries, which diverted attention from the lean gas internal combustion engine, efforts were centered upon the Diesel type of oil engine and again American manufacturers leaned for impetus upon their brother engineers across the water. Even the first hot-bulb type oil engines built in this country were built under license from a European concern.

American engineers were by no means lethargic in their attitude toward internal combustion engine design and many attempts were made to adapt American steam engine features, such as a modified Corliss valve action, to Diesel engine practice. Many and varied were the designs offered and frequent were the failures that resulted. This led to a natural prejudice against radical departures from established European practice.

More or less standardization of design gradually led to greater and greater adoption, in this country, of American designed engines and to an occasional sale of an American designed engine to a foreign country. Recently, as a culmination of the development of the American Diesel, a Belgian concern, which before the World War had an enviable reputation in the Diesel field, secured the rights for Belgium to build an American Diesel engine. This concern has already completed its first engine of 4000 hp., under this license and is now building a duplicate.

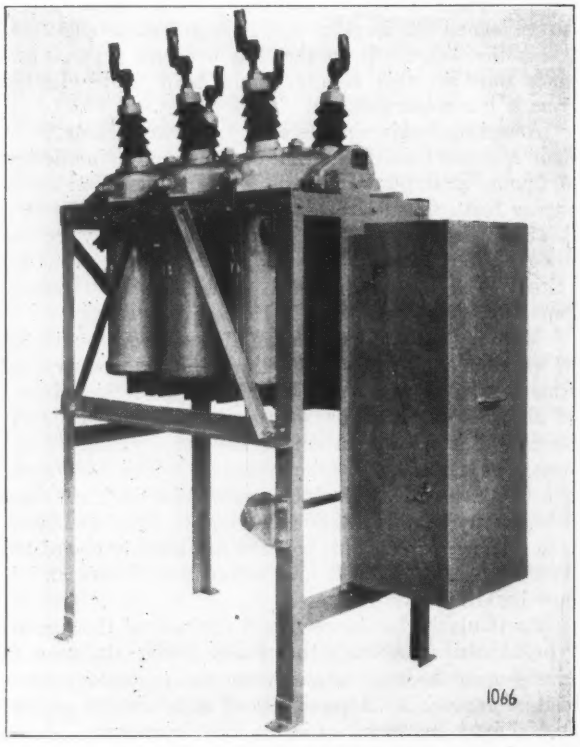
Particularly for large Diesel engines of the marine type, American manufacturers are giving attention to precision methods of manufacture and laboratory selection of materials. Larger use of alloy metals and of special heat treatment of steels may be expected in the future and, with the introduction of specialty manufacture of Diesel parts by concerns having specially equipped factories, in a manner similar to that which prevails here in the automobile industry, we may expect costs of manufacture of Diesel engines to decrease without decreasing the quality of the product. High costs of labor and of materials may be expected to be overcome eventually by American methods of manufacture, after which the American Diesel may well make its overtures for a place in the world market.

ANY CURVE which can be represented by a simple logarithmic equation such as $a = b^n$ becomes a straight line when plotted on logarithmic cross section paper.

Power Plant Engineering Developments and News

New Moderate Capacity Outdoor Oil Circuit Breaker

CONDIT ELECTRICAL MFG. Corporation has placed on the market a new outdoor oil circuit breaker of moderate interrupting capacity known as type 0-2 for outdoor distribution services at 15,000, 25,000 and 37,000 v.



CONDIT, TYPE 0-2 OIL CIRCUIT BREAKER

This circuit breaker is of sturdy, weatherproof construction throughout. The pole tops are fabricated of hot rolled steel plate and angles and are of novel design, affording a rigid foundation for the bushings and mechanism. A deep reënforcing flange extends down over the tank. The tanks are of heavy gage steel, elliptical in shape and heavily welded at the ends and bottom. The tank bottom is hot pressed and reënforced by angles which serve also as grounding lugs and a protection for the drain and sampling valves. A suitable tank lining is provided as a safeguard to prevent the arc from an abnormal circuit interruption from carrying to the tank wall. A gasket is provided around the tank top which effectively prevents oil throwing. The tanks are drawn up against this gasket and the pole tops by short tank bolts.

Condit laminated brushes are furnished protected on closing and opening by exceptionally large arcing contacts whose thermal absorption capacity materially reduces arcing on interruption.

The design of the operating mechanism embodies the highly important features of easy closure and at the same time affords ample pressure at the contact surfaces. A novel feature is the ability to locate the breaker control mechanism, such as hand-operated face plate solenoid or motor mechanism in any one of six positions. The mechanism as a whole is designed to secure that acceleration of the movable contact member during the opening of the circuit, which has proven to be the most efficient in circuit interruption.

Large one-piece solid porcelain type bushings of high mechanical and electric strength extending below the oil line and securely clamped to the pole top with water-tight gaskets provide more than ample insulation. Provision is made for two bushing type current transformers per pole. Series type current transformers mounted within the breaker tank may also be supplied if required. The pole units are mounted on a supporting framework of angle iron, rigidly and substantially constructed.

The type 0-2 oil circuit breakers are furnished for 400, 600 and 800 amp. The estimated interrupting capacity at the different voltages is given in the following table:

Volts	Kv-a.
15,000	200,000
25,000	150,000
37,000	100,000

Furnished manually or electrically operated (a.c. or d.c.). Electrically operated breakers may be arranged for automatic re-closing service of one of more closing cycles with constant power or varying time delay, affording minimum interruption to service.

Metal Oil Chambers, Leveling Plunger and Heavy Liquid Draft Gages

AS ILLUSTRATED in Fig. 1, the new line of draft gages introduced by Defender Automatic Regulator Co., St. Louis, Mo., has an all-metal oil chamber, 7 to which the inclined tube 9 is connected. For bringing the oil to zero on the tube, with draft connection closed

and the gage open to atmosphere, the plunger can be moved up or down by means of thumb nut 2 and locked in position by nut 3. Fresh oil can be added as needed through the plunger by removing screw.

Application of this improvement to an 8-scale gage is shown in Fig. 2. The upper inclined tubes are for draft over the fire and in the last pass of the boiler. The six vertical tubes are for wind box pressures. This type of gage is made with four to eight vertical tubes as desired, the tubes being either 3 in. or 7 in. high. For the 6-tube set with 3-in. scales, the size is 12 by 14 in.

Another new feature is shown in Fig. 3, a three-tube gage with lower pressure tube and oil chamber filled with a green liquid three times the weight of water so that the chamber can be of larger diameter and less height, thus getting it inside the case and giving a smaller gage. The bottom tube reads up to 6 in. water pressure for the wind box but a scale reading to 8 in. can be furnished. Top tubes, which use a red oil, lighter than water, for over-fire and uptake draft, can be furnished with any combination of scales desired.

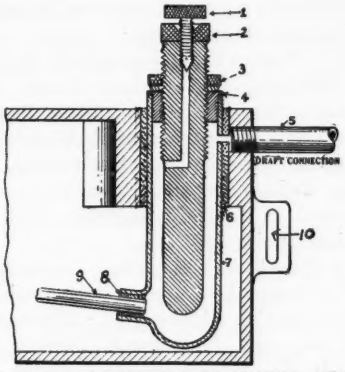


FIG. 1. ALL METAL CHAMBER AND LEVELING PLUNGER

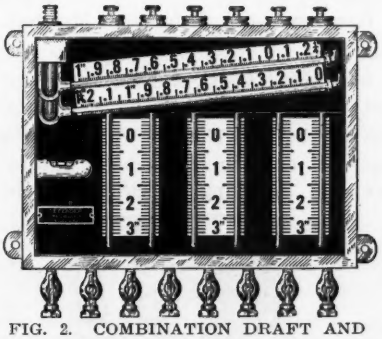


FIG. 2. COMBINATION DRAFT AND MULTIPLE PRESSURE GAGE FOR CHAIN GRATES

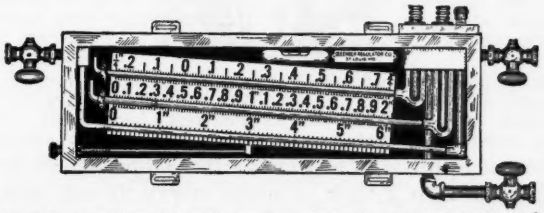


FIG. 3. THREE-TUBE GAGE FOR FORCED DRAFT STOKERS

Self-Sealing Turbine-Condenser Joints

THREE TYPES of joints, designed to allow for expansion so as to avoid strains on turbine casing or condenser shell, and in the expansion joint itself, to prevent transmission of vibration from turbine to condenser for the larger installations are illustrated herewith.

Figure 1 is a rubber tube joint, sealed by water pressure in a tubular gasket, the pressures used being from 10 to 20 lb. per sq. in., according to the distance between flanges. These have given good results where condenser temperature is maintained sufficiently low to permit the use of best quality rubber.

In Fig. 2 is shown a rubber tube joint as used on unit No. 8 at Hell Gate Station, provision being made for lateral movement by the ball bearings and for sealing by the water-cooled and expanded rubber tube.

A third type uses copper bellows with a single convolution, unattached to the flanges of turbine or condenser but sealed to them by flat springs which force the copper and its asbestos gasket against them. This type has proved successful for a year past in a high temperature exhaust. The installation shown is on a 4500-kw. unit. The compactness of the joint is evident, lateral as well as axial movement being possible. These joints are the product of The Dennis Engineering Co. of Columbus, Ohio.

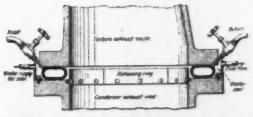


FIG. 1. ALDEN EXPANSION GASKET

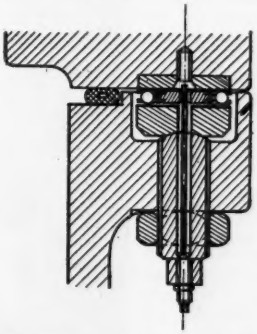


FIG. 2. FLEXIBLE EXPANSION JOINT ON HELL GATE NO. 8 UNIT FURNISHED BY BROWN-BOVERI CO.

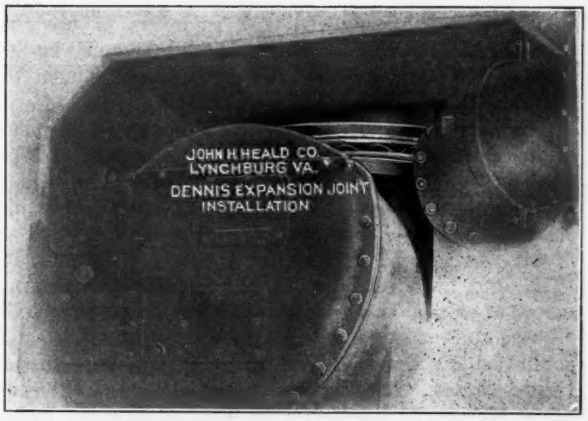


FIG. 3. COPPER BELLOWS EXPANSION JOINT FOR JOHN HEALD CO. SEALED BY SPRING PRESSURE

Death of John Anderson

JOHN ANDERSON, vice-president in charge of power of The Milwaukee Electric Railway & Light Co., Milwaukee, Wis., died on Monday, October 14, at St. Mary's Hospital in Milwaukee as the result of an infection contracted after another illness.

During his 17 yr. of service with the Milwaukee utility, Mr. Anderson won an international reputation for his pioneer work in building and operating pulverized coal plants and high-pressure boiler plants. Following experiments at the Wells St. plant in Milwaukee, he designed the Lakeside Station, stated to be the first power plant in the world to use pulverized coal exclusively.

In the same station, in 1926, there was also installed one of the first steam turbine-generators designed to operate at 1250 lb. steam pressure, the 1400-lb. pressure boilers supplying steam to it being fired by pulverized

JOHN ANDERSON

coal. He was among the first engineers to use the radiant heat superheater and resuperheater and was the inventor of many devices used in the development of pulverized fuel firing in central stations.

He was author of many technical papers, member of the A.S.M.E., member of Engineers Society of Milwaukee, honorary member N.A.P.E., district Boy Scout counselor and member of various fraternal organizations.

Mr. Anderson was born in Aberdeen, Scotland, in 1872, and was educated in the British government school of science and technology at Liverpool, England. He was apprenticed at the age of 13 to a machinist and engine builder, finished his term at 19 and came to the United States, where he was employed by the International Mercantile Marine Co. in 1890, as an oiler. From that time until 1906, he was on duty at sea almost continuously, filling every engineering position with the company up to that of chief engineer.

In 1898 he was first assistant engineer of the liner St. Paul, which was taken over by the Government during the war with Spain. Mr. Anderson served on board her with distinction throughout the war.

In 1906 Mr. Anderson left marine service to become engineer in charge of steam heating with the Union Electric Light & Power Co. of St. Louis. He held this position until 1912, when he was made chief engineer of the Milwaukee Electric Railway & Light Co.; he was made vice-president in charge of power in 1925.

During the World War, Mr. Anderson served as consulting engineer for the Transport Division of the United States Navy.

New Officers for A.S.M.E.

AS THE RESULT of the balloting for officers to head the American Society of Mechanical Engineers for 1930, the tellers of the election announce that the following have been chosen:

President, Charles Piez, chairman of the board, Link-Belt Co., Chicago, Ill.; vice-presidents, Paul Doty, chairman of the board, Minnesota State Board of Registration, St. Paul, Minn.; Ralph E. Flanders, manager, Jones & Lamson Machine Co., Springfield, Vt.; Ernest L. Jahncke, assistant secretary of navy, Washington, D. C.; Conrad N. Lauer, president, Philadelphia Gas Works, Philadelphia, Pa.

Managers, Harold V. Coos, Ford, Bacon & Davis, New York, N. Y.; James D. Cunningham, president, Republic Flow Meters Co., Chicago, Ill.; Clarence F. Hirshfeld, chief, research department, Detroit Edison Co., Detroit, Mich. The following were elected delegates to the American Engineering Council: L. P. Alford, Thomas D. Campbell, William B. Ferguson, Charles E. Ferris, John Lyle Harrington, William H. Kenerson, John H. Lawrence, and Richard C. Marshall, Jr.

Red Cross Roll Call

ANNUAL ROLL CALL for members in the American Red Cross will be held Nov. 11 to 25. The work of the Red Cross, not only in emergencies but in improving conditions and relieving suffering in the ordinary

routine of life is so well known that no praise can do it justice. It is a work in which everybody can have a part simply by answering the roll call and contributing such amount to support the work as he is able. The representatives of the Red Cross are worthy of cordial reception and support.

N. E. L. A. Prime Movers Committee Reports on Turbines

TURBINES is the subject of the publication No. 289-98, a serial report of the Prime Movers Committee of the National Electric Light Association, New York City,

which has just been received. The 1927 report presented the detailed operating record for steam turbines of 20,000-kw. capacity and larger for the year 1925. The present report presents a summary of the 1926 record of 153 turbines, 1927 record of 186 turbines and the detail 1928 record of 207 turbines.

An investigation of the turbine operating methods disclosed that there is no consistency in the time in which cold machines of equal capacity are brought up to speed and loaded. Neither was there found any definite relation between major turbine troubles and the machine operating methods.

Troubles incident to turbine blading form the greatest single cause of turbine outage. This presents a problem that requires most careful attention to details in design, manufacture and operation. In this connection, troubles due to deposits on turbine blading were reviewed. Although no method of cleaning blading which would be universally applicable was evolved, information presented should be helpful in suggesting a method of approach when these troubles are encountered.

Tests on turbine-generator units ranging in capacity from 6000 to 60,000 kw. are included. In previous years the tests reported were made with units operating straight condensing. In this report, tests are presented for some units operating on the regenerative cycle, with detailed data included on the performance of the extraction heaters. The effect on economy of varying exhaust vacuums and evaporator operation when the unit is operated with bleeding, also data for the same unit operated straight condensing and on the regenerative cycle, are included.

The report contains statements by operating companies on new installations, special tests and unusual operating experiences and manufacturers' statements on turbine blading, large turbines and auxiliary turbines.

News Notes

LABOR SAVING, material handling, new construction materials and designs, power transmission and connections, safety devices and many other factory and industrial appliances and supplies will be on display at the National Industrial Exposition to be held in Chicago, March 3 to 7, 1930.

That growth in industrial production must be accompanied by better methods in plant operation, elimination of old machinery and the acceptance of modern ideas covering better working conditions and plant upkeep, will be fully emphasized in the diverse exhibits of equipment, supplies and methods shown. National Industrial Exposition is expected to bring together executives of small industries as well as large who are able to recognize the importance of losses due to inefficiency, obsolescence and poor management.

SEVENTH ANNUAL CONVENTION of the American Institute of Steel Construction is to be held November 13 to 16 at the Edgewater Gulf Hotel, Edgewater Park, Miss. Complete details regarding the convention can be obtained from the secretary of the Association, 285 Madison Ave., New York.

ANNNOUNCEMENT was made recently from the headquarters of the National Electric Light Association that the 53rd convention of the Association will be held in San Francisco from Monday, June 16, 1930, to Friday, June 20. The convention will be held in the Municipal Auditorium. Consideration is being given to holding an exhibition of electrical machinery, equipment and appliances in connection with the convention. As this will involve the erection of a temporary structure for housing the exhibit, final decision on this point probably will not be made for several weeks. For many years, it has been customary for the Association to hold a convention on the Pacific Coast once every five years, having met in San Francisco in 1925, in Pasadena in 1920 and again in San Francisco in 1915 during the World's Fair.

AT BETHLEHEM CENTER, N. Y., a few miles south of Albany, is being constructed by the New York Power and Light Corp. a new substation, with an initial capacity of 12,000 kw., intended to give the city and the surrounding territory a greatly enlarged power supply and to eliminate almost entirely the possibility of interruption to service in this area. Energy will be received at the new substation at 66,000 v. over a new tower line from Unionville, where the line connects with the company's main transmission lines extending from the Rotterdam substation south to the line of the Central Hudson Gas & Electric Corp. at Catskill. This power will be stepped down at the new substation to 13,200 v. and will be transmitted to the Trinity Place substation at Albany, to the New York Central freight yards at Selkirk and to the substation at Voorheesville which supplies that village, Altamont, Slingerlands, Elsmere, Delmar and adjacent territory. The substation is being designed to provide for 110,000-v. operation and for greatly increased capacity as the demands for power increase.

COMBUSTION ENGINEERING CORP., American subsidiary of International Combustion Engineering Corp., New York, has announced three repeat orders aggregating more than $2,000,000 during one week. An award from the Bethlehem Steel Co. calls for four steam generators of 150,000 lb. an hour steam capacity each. These units are practically duplicates of the first installation of its kind recently made for Bethlehem to burn blast furnace gas in a completely water-cooled furnace. The Milwaukee Electric Railway & Light Co. purchased two duplicate Combustion boiler units fired by pulverized fuel and designed for a steam pressure of 1400 lb. per sq. in. A contract with Kansas City Power and Light Co. covers a duplicate Combustion boiler fired by what is stated to be the largest chain grate stoker burning bituminous coal.

HIBBARD S. GREENE, former vice-president and director of the Barber-Greene Co., Aurora, Ill., has been appointed assistant to the president of Chain Belt Co., Milwaukee, Wis. Mr. Greene will coördinate the marketing plans of the Chain Belt Co., Sivyer Steel Casting Co., Federal Malleable Co. and the Interstate Drop Forge Co., all of Milwaukee, Wis., as well as The Stearns Conveyor Co. of Cleveland, Ohio, the latter a division of the Chain Belt Co. Mr. Greene's headquarters will be at the Milwaukee plant of the Chain Belt Co.

AT VAUGHN, N. M., The Inland Utilities Co. is installing a light and power plant consisting of two Fairbanks-Morse Semi-Diesel units of 100 hp. and 150 hp. capacity. Work is being rushed to completion under direction of S. N. Daily, erecting engineer from the Kansas City offices. Operation of the plant will be supervised by H. W. Wright, Local Superintendent.

RALPH E. DODSON, former manager of the Cincinnati office of Keasbey & Mattison Co., is now special representative for the Ric-wiL Co., Cleveland, Ohio. Mr. Dodson will have his headquarters in the Chicago office of the Ric-wiL Co. at 724 Harris Trust Bldg., Chicago, Ill.

HOMESTEAD VALVE MFG. CO., INC., Coraopolis, Pa., has appointed C. E. Ruth, formerly of the engineering department of the Rust Engineering Co., as district sales manager in the district including northern Pennsylvania, Ohio, western New York and Ontario.

W. R. EBERHARDT, for 10 yr. structural engineer and contract engineer for The H. K. Ferguson Co., Hanna Building, Cleveland, Ohio, has been appointed manager of his company's New York Branch Office at 25 West 43rd St., New York City. During the past year he has been in charge of several large chemical plant operations which The H. K. Ferguson Company is building at various points in the East. Eberhardt is also vice president of the Eberhardt-Ott Electric Co., of Cleveland. He is a member of the American Society of Civil Engineers.

L. A. BENSON & Co., of Baltimore, has been appointed distributor by the Diamond Chain & Mfg. Co., Indianapolis, Ind.

MERRILL L. HARRY, general manager of the Central Illinois group of the Illinois Power & Light Corp. properties, was fatally injured the night of Oct. 11 in an automobile accident near Illiopolis, Ill., as he was returning from a tour of inspection of properties in that district. He had been identified with utilities interests and operation in central Illinois for a quarter of a century. He was born June 8, 1878, in Bay City, Mich. He gained his first experience in the electric plant which his father established there and later studied traction operation in the line which his father operated.

ST. LOUIS has been designated as district headquarters of one of the 10 districts that comprise the General Electric Supply Corp. of Delaware, a new organization formed by consolidation of 14 supply corporations owned by the General Electric Co. throughout the United States, it was announced recently. E. A. Oas, formerly of St. Paul, Minn., has been named manager of the St. Louis district.

WITHIN THE NEXT SIX MONTHS, it is expected that the hydro-electric development at Muscle Shoals will be utilized by the Tennessee Electric Power Co. of the new Commonwealth and Southern system to supply the growing industrial center of Nashville, Tenn. The Tennessee company is planning to establish a transmission line connecting Muscle Shoals with Nashville, Chattanooga and other sections served by the company.

ADDITION of 86,000 hp. to the hydroelectric development of the upper Hudson River, 52,000 hp. of which will be secured by enlargement of the Spier Falls plant, is being secured by the New York Power & Light Corp., according to a recent announcement from the company offices at Albany. The addition to the Spier Falls plant will raise its capacity to 100,000 hp. and the total of the Mohawk Hudson system to 550,000 hp. Further increases in power expansion on the upper Hudson River district are forecast in recent reports that the Mohawk Hudson Corp. is negotiating with the Union Bag and Paper Co. at Hudson Falls for power rights, to involve construction of a new plant in Fennimore to develop 75,000 hp. The first of the new plants for the Mohawk-Hudson system to be placed in operation will be a 34,000-hp. unit just below the Conklingville dam on the Sacandaga River. This is now under construction and is scheduled for operation next April. The present capacity of the Spier Falls station is 48,000 hp. The addition of 54,000 hp. capacity is to be completed for service in December, 1931.

H. E. BRELSFORD, former chief engineer of the technical department of the United States Shipping Board and more recently works manager of the Buffalo Works of the Worthington Pump & Machinery Corp., is now in charge of the Research Department of Diamond Power Specialty Corp., Detroit, Mich.

H. C. RAMSEY has been appointed vice-president in charge of international business of Worthington Pump & Machinery Corp., Harrison, N. J. In addition to the export department at New York, this division will include the European associated companies. At the same time, W. B. Strong was made manager of the export department at New York, a position formerly held by Mr. Ramsey. For the present, the new vice-president will make his headquarters with Worthington-Simpson, Ltd., London.

GENERAL GAS & ELECTRIC CORP., 50 Pine Street, New York, has added a third unit to its steam operated electric generating plant at Parr Shoals, S. C., increasing the capacity from 42,500 kw. to 72,500 kw. The plant adjoins, and is operated in conjunction with, a hydroelectric station in order to provide an uninterrupted supply of power for this district. A large portion of the output is being taken by the Duke Power Co. for its requirements in the northern part of South Carolina.

PALMER-BEE Co., Detroit, Mich., announces the appointment of Geo. M. Demorest as district representative for Pittsburgh and vicinity.

FRANK HENDERSON, manager of the Cleveland office of Combustion Engineering Corp., died suddenly, Wednesday, Sept. 25, in his 53d yar. He was born at Tuscola, Ill., Feb. 11, 1876, and joined the Green Engineering Co. in 1898. He worked his way up in that organization as service man, tester and superintendent of service work. In 1922, when the Green Engineering Co. was absorbed by Combustion Engineering Corp., Mr. Henderson, who was then managing the Cleveland office, became the district manager for Combustion Engineering Corporation, in which position he continued until his death.

ALLIS-CHALMERS MFG. Co. recently received orders covering heavy power plant equipment for three utility companies, aggregating approximately $2,000,000. One order covers six 33,500-hp. hydraulic turbines, together with parts for two additional units. These are for the Osage Development of Union Electric Light and Power Co., St. Louis, Stone & Webster Engineering Corp., Engineers. A 30,000-kw. steam turbine unit has been ordered for the Oklahoma Gas & Electric Co., a Byllesby property, the second unit of this size recently furnished that company. Two large umbrella type water wheel generators, each of 31,111-k.v.a. capacity, for the Carpenter Development of Arkansas Power & Light Co., near Hot Springs, Ark., were purchased by the Phoenix Utility Co., the Engineering Division of Electric Bond & Share Co.

YARNALL-WARING Co., Philadelphia, Pa., has appointed Roger A. Martin as its Southeastern representative, succeeding Samuel D. Barr, who recently resigned.

Catalog Notes

PUBLICATION No. 289-86 of the Hydraulic Power Committee, N. E. L. A., 420 Lexington Ave., New York City, contains a bibliography of published material on hydroelectric work and a number of statements by manufacturers. The latter cover various types of water wheels, valves and accessories and describe equipment that is under construction or installation in several important hydroelectric plants.

SECOND EDITION of the Brown Flow Meter Catalog, No. 21, a 90-page book containing a complete presentation of the general theory, use, design and practical application of the flow meter, with a detailed and well-illustrated description of the principle, construction and features of the Brown electric flow meter, has just been issued. Descriptions and illustrations of this flow meter show the utilization of the inductance bridge principle, the mercury seal, automatic recording planimeter and other features. In addition, the catalog shows a number of instruments the design of which is an adaptation of the Brown electric flow meter operating principle and construction, such as the motion transmitter and the electric liquid level recorder. The book contains 126 illustrations and is handsomely printed. Copies of this new Catalog No. 21, may be obtained from the Brown Instrument Co., Philadelphia, Pa.

BUYERS' GUIDE of nickel alloy steel products, covering almost every conceivable form, from armor plate to welding wire, is issued by the International Nickel Co., 67 Wall St., New York, N. Y.

TORCHWELD WELDING AND CUTTING EQUIPMENT is described in detail in Catalog 29 issued by Torchweld Equipment Co., 224 No. Carpenter St., Chicago, Ill. This 40-page illustrated bulletin describes the equipment in detail and gives price lists of all the principal parts and accessories.

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

required by the Act of Congress of August 24, 1912, of Power Plant Engineering, published semi-monthly at Chicago, Ill., for October 1, 1929.

State of Illinois, } ss.
County of Cook, }

Before me, a Notary in and for the State and county aforesaid, personally appeared Charles S. Clarke, who, having been duly sworn according to law, deposes and says that he is the Secretary of the Power Plant Engineering and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to-wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:
Publisher, Technical Publishing Co., Chicago, Ill.
Editor, Arthur L. Rice, Chicago, Ill.
Managing Editor, R. E. Turner, Chicago, Ill.
Business Manager, E. R. Shaw, Chicago, Ill.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)
Technical Publishing Co., Chicago, Ill.
E. R. Shaw, Chicago, Ill.
Arthur L. Rice, Chicago, Ill.
K. L. Rice, Chicago, Ill.
Charles S. Clarke, Chicago, Ill.
W. A. Phillis, Cleveland, Ohio.
R. E. Turner, Chicago, Ill.
A. W. Kramer, Chicago, Ill.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.)
There are none.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

CHAS. SANFORD CLARKE, Secy.

Sworn to and subscribed before me this 4th day of October, 1929.

[Seal.] ANTON O. LANDES.
Notary Public.

(My commission expires April 26, 1930.)